Message from the APSCC 2010 General Conference Chairs and Program Committee Chairs

Welcome to Hangzhou and to the joint 2010 IEEE Asia-Pacific Services Computing Conference (APSCC 2010), held at Hangzhou, Zhejiang Province, China, Dec. 6–10, 2010. Previous IEEE APSCC conferences were held in Guangzhou, China (2006), Tsukuba Science City, Japan (2007), Yilan, Taiwan China (2008), Biopolis Singapore (2009). As the fifth event in the increasingly popular series, APSCC 2010 expects to attract outstanding researchers from all over the world to Hangzhou—the world famous beautiful city in China—and continues to establish the status of IEEE APSCC as one of the major conferences on the services computing.

Services computing is a new cross-discipline that covers the science and technology needed to bridge the gap between business services and IT/telecommunication services. The goal of services computing is to develop new computing technology and thereby enable more advanced IT/telecommunication services to support business services more efficiently and effectively.

To strengthen academic exchanges and discussions on the fields of services computing, the 2010 IEEE Asia-Pacific Services Computing Conference (APSCC 2010) will be held on Dec. 6–10, 2010 in Hangzhou West Lake, Zhejiang Province, China. It will provide a five-day meeting on services computing. The following keynote speakers are invited to further explore these topics: Wentong Cai (Nanyang Technological University, Singapore) Christophe Cérin (University of Paris XIII, France), Chen, Junliang (Beijing University of Posts and Telecommunications, China). The General Conference Chairs of APSCC 2010 would like to thank all the keynote speakers for their innovative and inspiring speeches delivered in the conference.

Concurrent sessions will cover a wide range of topics and issues, including both contributed papers and workshops developed on specific topics, all with a central focus of service computing theory, methods and applications. This year, we also have three workshops that complemented APSCC 2010 program with contributions for specific topics: the International Workshop on Quality of Service Management of Wireless Networks 2010 (IWQSWN 2010), organized by Prof. Changhua Wu (Kettering University, USA), Prof. Weihua Sheng (Oklahoma State University, USA) and Dr. Wei Zhang (Hangzhou Dianzi University, China); The International Workshop on Ubiquitous Network Computing 2010 (UNC 2010) organized by Prof. Neal N. Xiong (Georgia State University, USA) and Dr. Jong Hyuk Park (Kyungnam University, Korea); The 2010 International Workshop on Construction and Maintenance for Service-Oriented Software (CmSOS 2010) organized by Prof. Jianwei Yin (Zhejiang University, China) and Prof. Xiaofei Xu (Harbin Institute of Technology, China). The Program Committee Chairs of APSCC 2010 would like to thank all the workshops chairs for their excellent works and effort in organizing these workshops.
IEEE APSCC 2010 is an important forum for researchers and industry practitioners to exchange information regarding advancements in the state of art and practice of IT/telecommunication-driven business services and application services, as well as to identify emerging research topics and define the future directions of services computing.

APSCC 2010 received more than 360 submissions (including 258 main track papers and 110 workshop papers) from more than 25 countries and regions. All submitted papers have to go through a rigorous reviewing process. Each submission was reviewed by at least two independent reviewers in a standard peer review process. After rigorous peer review, we finally select 101 papers (acceptance rate of main conference is 24.8%, acceptance rate of workshops is 30.1%). We emphases that our policy is to guarantee the high-quality of the accepted papers and at the same time encourage more people to participate in the conference.

APSCC 2010 is cosponsored by the Institute of Electrical and Electronics Engineers, the IEEE Computer Society, IEEE Computer Society Technical Committee on Services Computing (TCSC), Natural Science Foundation of China, Hangzhou Dianzi University. Their sponsorships support the success of this conference.

We thank Hazel Kosky (Conference Services Coordinator of IEEE Computer Society), Elizabeth Brookes Little (Meeting Planner, Conference Operations Group, IEEE Computer Society), Andrea L. Thibault-Sanchez (CPS Quotes & Acquisitions, Conference Publishing Services, IEEE Computer Society), Randall Bilof (CPS Editor, Conference Publishing Services, IEEE Computer Society). APSCC 2010 would not have been successful without their excellent services.

We would like to thank the program chairs, organization committee, and program committees for their hard work.

We hope that APSCC 2010 will be successful and enjoyable to all conference participants. We also hope all participants can share and exchange ideas at APSCC 2010. We look forward to seeing you next year at APSCC 2011!

Wolfgang Gentzsch, Open Grid Forum, Germany
Jian Wan, Hangzhou Dianzi University, China
General Conference Chairs

Song Wu, Huazhong University of Science and Technology, China
Bingbing Zhou, University of Sydney, Australia
Program Committee Chairs
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An Efficient Analysis for Reliable Data Transmission in Wireless Sensor Network

Department of Computer Engineering
Kyung Hee University
Yongin-Si, Korea
{gawon, junhyung, seungjin, johnhuh}@khu.ac.kr

Abstract—Ubiquitous technology through sensor networks is being applied to numerous industrial fields specially to increase the quality of human life (QoL). Therefore, Wireless Sensor Networks (WSNs) lossless data is one of the communications challenges to provide accurate data. Although, end-to-end data retransmission has evolved as a reliable transportation in Internet, this method is not applicable to WSNs due to the lack of reliability of wireless link and resource constraints in sensor nodes. In our previous paper, we proposed a reliable data transfer using path-reliability and implicit ACK called RTOD on WSN. However, path reliability calculation components such as RSSI, channel error rate, number of transmission in RTOD method have not been studied thoroughly. In this paper, we analysis path reliability components and simulate by using NS-2. Moreover, we propose limited number of transmission method (LTM) for WSNs. Proposed scheme shows average 4.1% fault tolerance.

Keywords—WSN; Reliable Data Transfer; Number of Transmission

I. Introduction

In recent years, wireless sensor networks (WSNs) have become broader from simple environmental surveillance and information delivery to various mission critical fields such as u-Healthcare service, u-Agriculture system and u-Defense. These applications require assured delivery of high-priority events to sinks, reliable control and management of sensor network structure, and remotely programming/re-tasking sensor nodes in a controlled, reliable, robust and scalable manner [3]. That is, these applications necessitate all data to be transmitted without loss in WSNs.

However, unlike traditional networks (e.g., IP networks) reliable data transmission is still a big challenge in WSN environment. WSNs are highly distributed self-organized systems. They rely on significant numbers of scattered low-cost tiny devices/sensor nodes featuring strong limitations in terms of processing, memory, communications and energy capabilities. Since sensor nodes are highly resource constrained, design of a reliable data transmission protocol is very difficult and challenging task.

There are many transport protocols proposed and implemented in the literature to improve reliability in WSNs. These protocols are mainly designed 1) to confirm data transfer and lost data recovery by using Acknowledgement (ACK) or Negative Acknowledgement (NACK) based approaches [2-6], 2) to increase data transfer success rate by using Multiple Path approaches [7-9], and 3) to avoid data collision by using Event based approach and collision detection approach [10][11]. And 4) to find good quality path for data transference by using apply reliability approach [12]. To achieve lossless reliable data transfer, those data transmission protocols commonly select type of feedback message or recovery factors such as ACK, NACK, hop-by-hop recovery, end-to-end recovery, the number of packet duplication. And to apply reliability on routes for data transfer, reliability approach use channel error rate. However, those static quality based parameters have limitations in case of the error-prone and unstable WSNs, because they do not apply dynamic conditions in sensor nodes. Moreover, previous approaches focus on minimum data loss without considering energy consumption. These lifespan of sensor and unreliable nature of WSNs occur two trade-off problems: energy consumption and lossless data transfer.

Nevertheless, few studies have been devoted to the design of reliable transport protocols using path reliability for sensor networks. This approach was primarily used to choose reliable paths based on directed diffusion in case of delay-sensitive data delivery over error prone WSNs [12]. Channel error rate was mainly used to measure path reliability. However, this mechanism cannot ensure end to end reliability in WSNs environment which is important for mission critical applications.

In previous paper, we proposed a reliable transmission method called RTOD [1] by calculating the reliability of every node path using the power level RSSI value of sensor nodes and the network channel error rate. Moreover, our proposal employed overhearing as an implicit ACK to guarantee reliability. Furthermore, to maximize energy efficiency we defined optional ACK mechanism to delegate direct ACK or use implicit ACK (denoted to ACKimp) according to reliability. The proposed protocol enables a quick error-recovery of PSFQ [3] while maintaining the generic ACK/NACK reliability. Also, optional ACK mechanism is executed by comparing current path reliability and base reliability to delegate acknowledgement mechanism achieving more efficient energy consumption. Various simulations were conducted to show the effectiveness of RTOD as compared to some existing algorithms in terms of energy consumption and traffic waste reduction.

However, these components for calculate path reliability have not been studied yet. In this work we focus on the features of components and propose limited number of
transmission for WSNs. The decision of the number of transmission can be solved using simulated results.

In this paper, we analyze path reliability components for reliable transmission in the RTOD method such as RSSI, channel error rate and number of transmission. The objective is to verify path reliability calculation and to support limited number of transmission due to WSNs wireless nature.

The rest of this paper is organized as follows: Section 2 introduces some fundamental factors that determine path-reliability and well known reliable transfer schemes with their problems. Section 3 describes the proposed idea. The simulation results are described in section 4. At last, conclusions of our work are detailed in section 5.

II. RELATED WORK

In this section, first we summarize some issues and problems on sensor network regarding reliable transmission. Then, we briefly review some basic approaches for reliable data transfer in wireless sensor networks showing how our research builds on previous work.

A. Reliable transmission

Previous work has been done in reliable transport for WSNs. A common reliable data transfer approach can be classified as 6 main categories as shown in Table 1. As noted these can be broadly divided in ACK / NACK based scheme, multi-transfer scheme, collision avoidance scheme, reliability scheme. In other words, an ACK/NACK based error-recovery method, a method creating multiple packets transfer through multi-path according to the required reliability, a method avoiding data transfer collisions and controlling the number of transfers depending on event, and a method applying reliability considering the channel error rate in routing. In particular, ESRT and RMST are methods that guarantee reliability in upstream transfers and GARUDA and PSFQ guarantee downstream reliability. Table 1 shows the categorization of methods.

<table>
<thead>
<tr>
<th>TABLE I. RELIABLE DATA TRANSFER METHOD ON WSN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>ACK/NACK heuristic</td>
</tr>
<tr>
<td>reliability scheme</td>
</tr>
</tbody>
</table>

In [1], our previous paper proposed a reliable transmission using overhearing and delegation called RTOD. RTOD has follow features: 1) objective is to achieve energy-efficiency and less overhead on transport layer using path reliability based on RSSI signal and channel error rate. 2) In this scheme, overhearing problems are used as advantage for implicit acknowledgement mechanism. 3) Optional ACK mechanism is executed by comparing current path reliability and base reliability to delegate acknowledgement mechanism achieving more efficient energy consumption. 4) To achieve reliable transfer in WSNs several scenarios are discussed, implemented and tested. However, RTOD have not considered limited number of transmission.

In [12] a reliable data transfer mechanism using directed diffusion in WSNs is proposed. This mechanism involves selecting a path with higher reach-ability and transferring data along the path chosen, which is based on the end-to-end reliability calculated by the dissemination procedure of Interest packets, while each node of a sensor network maintains only the information on its neighborhood. It only considers channel error rate for routing path reliability.

B. Received signal strength

Received signal strength indicator (RSSI) is a power measurement present in a received RF signal. RSSI is a generic radio receiver technology metric which is usually invisible to the user but directly known to users of IEEE 802.11 wireless networking protocols.

RSSI is the relative received signal strength in a wireless environment employing IEEE 802.11 expressed in arbitrary units. RSSI can be used internally in a wireless networking card to determine when the amount of radio energy in the channel is below of a threshold point where the network card is clear to send (CTS). Once the card is clear to send, a packet of information is sent. The end-user will likely observe an RSSI value when measuring the signal strength of a wireless network through the use of a wireless network monitoring tool.

RSSI measurements are unit less and ranges from 0 to 255 expressible as a one-byte unsigned integer. The maximum RSSI value is vendor dependant i.e. Cisco Systems cards returns a RSSI value from 0 to 100 and Wi-Fi chipset returns an RSSI value from 0 to 127 (0x7f) with 128 (0x80) indicating an invalid value.

C. Retransmission

Retransmission is the resending of packets which have been either damaged or lost. It is a term that refers to one of the basic mechanisms used by protocols operating over a packet switched computer network to provide reliable communication. Such networks are usually 'unreliable', meaning they offer no guarantees that they will not delay, damage, or lose packets, or deliver them out of order. Protocols which provide reliable communication over such networks use a combination of acknowledgments, retransmission of missing and/or damaged packets, and checksums to provide that reliability [13].

III. LTM : LIMITED THE NUMBER OF (RE)TRANSMISSION METHOD

A. Background

Reliable data transfer using each path-reliability in WSNs has not been discussed in any literature. The primary motive of RTOD is to provide end to end reliable data delivery in WSN environment with minimum energy expenditure. It uses each path reliability approach to select between direct
ACK and implicit ACK. It measures the path reliability using RSSI and channel error rate. It also considers energy efficiency through minimize the number of transmission time by reduce the number of ACK messages. In the previous research [1], channel error rate has only been applied to path reliability. But as the operating condition of each node is influenced by current network environment, the channel error rate varies at each time. Moreover, WSNs are composed of low energy power sensor nodes which are capable of sensing particular physical phenomena in their vicinity and communicating among themselves using wireless transceivers. These low power and wireless data communication features make WSN data dissemination unreliable. Therefore, we define the reliability as the combination of Channel Error Rate (CER) with RSSI that represents the signal strength of neighbour for apply varying network condition. RSSI is proportional to input power level[14], reliability using RSSI reflect the current remain sensor node power level.

B. Limited number of transmission consideration

One of the basic features is periodicity in WSNs. Most applications in environment, military and medical treatment obtain data and transmit it periodically. If there were no limited total number of transmissions in WSNs, it could cause disadvantages due to wireless communication nature. First, emergency data transfer could fail while re-transmission to recover the failure packets. Second, energy consumption will be higher than limited total number of transmission networks. If packet dissemination fail, sender had to retransmit packets infinitely until receiver successfully receive the packet. In the majority of cases, the networks limit the number of total transmission to prevent infinite transmission. These manners are one of key elements to support QoS for high performance in all kinds of networks. In WSNs, total number of transmission will be lower than the other networks on account of low capacity of sensor nodes. In this paper, we apply Limited the number of Transmission Method called ‘LTM’ to RTOD over WSNs.

To verify failure when we apply only reliability in limited number of transmission network, we conducted some experiments. The simulations were managed with 10 lined nodes and single path topology. Network conditions including packet loss rates and channel error rates are randomly allocated within the range of error rate parameter configuration in overall network. The reachability is the ratio of the number of packets arrived at the sink node to the number of packets sent by a source node [15].

The result shown in Figure 1 converges into 1 when the number of re-transmission is limited to 5 by NS-2 simulator generating transmission success rate for ACK, PSFQ, NACK, and RTOD schemes. The results of our proposal converges into 1 with error rate 0%, 20%, 40%, 60%, 80% when number of re-transmission is limited at 5, as well. Hence, the number of re-transmission condition is set to 5 for the remaining experiments and to 1 for initial number of transmission to make a total of 6 transmissions.

C. Maintaining the Integrity of the Specifications

To set a periodic transmission we assume a time limitation for data transfer on sensor network. If implicit ACK is always used even when path reliability is higher than base path reliability and total number of transmission is limited under 2, the node cannot confirm transmission successful or fail. We simulate data transmission between \( A-B \) nodes with 40% channel error rate and 80% of RSSI as shown in Figure 2. If the number of transmissions is set to 2, 20% failure occurs but an average of re-transmissions observed by 1.84. Therefore, it is clear that the number of re-transmissions is also required consideration for reliable transmission.

To examine the correlation between the number of re-transmissions and RSSI, we analyse the channel error rate to use the direct ACK in Figure 3.
From the Figure 3, the correlation analysis for RSSI and CER is as follows:

Where,
- \( x \): mean number of transmission of sample for RSSI
- \( y \): mean number of transmission of sample for channel error rate
- \( n \): sample size

\[
P_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} = -0.9605 \quad \ldots (4)
\]

If absolute value converges into 1 means more correlation as shown for RSSI and channel error rate. Therefore, there is small influence on reliability calculation even though only one of them is used. However, these two elements need to be applied separately due to confliction of redundancy and near-far problem on network layer.

Table II shows representative values of simulation results in Figure 2. To get desired number of transmission \( R_{iT_i} \) on node \( i \), we simply add average and standard deviation. When data is transferred, each node decides direct/implicit ACK according to the path reliability and required the number of re-transmissions.

### Table II. Representative Value of Data 1 Packet Transmission on Node i Simulated in Figure 7

<table>
<thead>
<tr>
<th>Representative Value</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2</td>
<td>middle value on node i transmission</td>
</tr>
<tr>
<td>Mode</td>
<td>2</td>
<td>mode value on node i transmission</td>
</tr>
<tr>
<td>Average</td>
<td>1.83</td>
<td>arithmetic average on node i transmission</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.7528</td>
<td>standard deviation on node i transmission</td>
</tr>
<tr>
<td>Average + Standard Deviation</td>
<td>2.5828</td>
<td>necessity number of transmission on node i</td>
</tr>
</tbody>
</table>

According to previous simulation results, we calculate minimum number of transmission \( R_{iT_i} \) as follows:

Minimum Number of Transmission

\[
R_{iT_i} = m + \sqrt{\frac{n \sum m^2 - (\sum m)^2}{n(n-1)}} \quad \ldots (5)
\]

Where,
- \( m \): mean number of transmission on node \( i \).
- \( n \): sample size

Moreover, when the mean plus standard deviation value is used i.e. 2.5996 along with transmission time limitation set to 3 the data transmission is more reliable than only applying average value 1.84 as simulation results in Figure 2.

### D. Appropriate number of transmission for Channel error rate and RSSI

We can apply two kinds of methods for ACK decision in RTOD with applying proposed L.

1. One method is rigid way. It uses direct ACK for data transfer since we do not know node \( i \)'s required number of transmission. After that, if \( R_{iT_i} \leq N_{iT_i} \) then implicit \( ACK_{imp} \) is applied otherwise it uses direct ACK according to modified path quality.

2. The other method is flexible where the node sets required number of transmission \( R_{iT_i} \) to a simulated value and compares it to the network’s required number of transmission \( R_{iT_i}' \). If \( R_{iT_i} \leq N_{iT_i}' \), implicit \( ACK_{imp} \) is initially applied and when path quality decreases direct ACK is used. Hence, if initially \( R_{iT_i} > N_{iT_i} \) direct ACK is used and when path quality increases \( R_{iT_i} \leq N_{iT_i} \) implicit \( ACK_{imp} \) is applied.

The second method is more efficient than the first one for reduction of ACK messages. So in this paper, we apply the second method for ACK decision when the number of
transmissions is limited. Briefly, initial RT\textsubscript{i} is set following the second flexible way in RTOD.

Optional ACK is based on required number of transmissions simulated using NS-2 tool which results are listed in Table III. Table IV shows required number of transmission on various channel error rates and RSSI conditions.

### Table III. Number of Transmission Requirement for Channel Error Rate

<table>
<thead>
<tr>
<th>Channel Error Rate(CE)</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Average + Standard Deviation</th>
<th>Number of Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ~ 10</td>
<td>0.13</td>
<td>0.1380</td>
<td>0.2680</td>
<td>1</td>
</tr>
<tr>
<td>10 ~ 20</td>
<td>0.42</td>
<td>0.2960</td>
<td>0.7160</td>
<td>1</td>
</tr>
<tr>
<td>20 ~ 30</td>
<td>0.76</td>
<td>0.4292</td>
<td>1.1892</td>
<td>2</td>
</tr>
<tr>
<td>30 ~ 40</td>
<td>1.25</td>
<td>0.5000</td>
<td>1.7500</td>
<td>2</td>
</tr>
<tr>
<td>40 ~ 50</td>
<td>1.95</td>
<td>0.3611</td>
<td>2.5111</td>
<td>3</td>
</tr>
<tr>
<td>50 ~ 60</td>
<td>2.83</td>
<td>0.4775</td>
<td>3.3075</td>
<td>4</td>
</tr>
<tr>
<td>60 ~ 70</td>
<td>3.68</td>
<td>0.2369</td>
<td>3.9169</td>
<td>4</td>
</tr>
<tr>
<td>70 ~ 80</td>
<td>4.31</td>
<td>0.3127</td>
<td>4.6227</td>
<td>5</td>
</tr>
<tr>
<td>80 ~ 90</td>
<td>4.72</td>
<td>0.2513</td>
<td>4.9713</td>
<td>5</td>
</tr>
<tr>
<td>90 ~ 100</td>
<td>4.83</td>
<td>0.4672</td>
<td>5.2972</td>
<td>6</td>
</tr>
</tbody>
</table>

### Table IV. Number of Transmission Requirement for RSSI

<table>
<thead>
<tr>
<th>RSSI (-100) ~ (-90)</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Average + Standard Deviation</th>
<th>Number of Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-100) ~ (-90)</td>
<td>4.82</td>
<td>0.4216</td>
<td>5.2416</td>
<td>6</td>
</tr>
<tr>
<td>(-90) ~ (-80)</td>
<td>4.48</td>
<td>0.3472</td>
<td>4.8272</td>
<td>5</td>
</tr>
<tr>
<td>(-80) ~ (-70)</td>
<td>3.49</td>
<td>0.5671</td>
<td>4.0571</td>
<td>5</td>
</tr>
<tr>
<td>(-70) ~ (-60)</td>
<td>3.21</td>
<td>0.3319</td>
<td>3.5419</td>
<td>4</td>
</tr>
<tr>
<td>(-60) ~ (-50)</td>
<td>3.02</td>
<td>0.2147</td>
<td>3.2347</td>
<td>4</td>
</tr>
<tr>
<td>(-50) ~ (-40)</td>
<td>2.88</td>
<td>0.3716</td>
<td>3.2516</td>
<td>4</td>
</tr>
<tr>
<td>(-40) ~ (-30)</td>
<td>2.49</td>
<td>0.4424</td>
<td>2.9324</td>
<td>3</td>
</tr>
<tr>
<td>(-30) ~ (-20)</td>
<td>1.39</td>
<td>0.1361</td>
<td>1.5261</td>
<td>2</td>
</tr>
<tr>
<td>(-20) ~ (-10)</td>
<td>0.42</td>
<td>0.1151</td>
<td>0.5351</td>
<td>1</td>
</tr>
<tr>
<td>(-10) ~ (-0)</td>
<td>0.24</td>
<td>0.0964</td>
<td>0.3364</td>
<td>1</td>
</tr>
</tbody>
</table>

To transfer data in RTOD, the node compares base reliability and current reliability. Through apply LTM, node compares the number of minimum re-transmission and the current network re-transmission limit. Based on these comparisons, direct ACK or implicit ACK\textsubscript{mp} is selected. Hence, RTOD and LTM combined method considers direct/implicit ACK as node ACK\textsubscript{mp} through the node’s i number of re-transmission, as well.

### IV. Simulation

#### A. Environment

The simulations are executed over a uniform topology consisting of 0–100 nodes deployed in a square grid form of 100m x 100m in NS-2 network simulator. Network conditions are randomly allocated within the range of error rate parameter configuration. For example, if the range of error rate is 50%, random rate values from 0% up to 50% are assigned to the packet loss rate and the channel error rate respectively. Each sensor node maintains the history of packet loss rates and a channel error count.

We applied a network interface and an error model basically included in NS-2 package. To simplify the analysis, the traffic type is CBR (Constant Bit Rate) which generates packets periodically. The IEEE 802.15.4 package for NS-2 is used in the simulation. The maximum bandwidth is 250kbps and the frames are transferred at a rate of 1 frame per second.

#### B. Fault tolerance with the number of transmission limitation

The goal of the simulation shown in Figure 5 is to examine LTM reliability for a period of time according to node RSSI and channel error rate proposed in chapter 3. We consume that there is a certain network limited number of transmission defined in matching Table V, we proceed to validate chapter 3. Hence, to identify data transfer success, the number of sent packets is compared to the number of arrived packets in a certain period of time.

### Table V. 6 Cases Simulation Condition and Number of Minimum Required Transmission on Matching Table

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Simulation Condition</th>
<th>Number of Minimum Transmission Required RT\textsubscript{i}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Channel Error Rate 15, RSSI -15</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Channel Error Rate 15, RSSI -25</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Channel Error Rate 25, RSSI -35</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Channel Error Rate 50, RSSI -50</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Channel Error Rate 75, RSSI -75</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Channel Error Rate 80, RSSI -90</td>
<td>6</td>
</tr>
</tbody>
</table>

The conditions of the simulation are defined in Table V. The number of nodes used in the experiment 0 to 100, and data is transferred by increasing 10 nodes per trial up to 100, i.e. 0, 10, 20... 100. The experiment is tested by 100 in each case as shown in Figure 4 to get the average value.

The simulated numbers of transmission are not exceeding the number of minimum transmission time required RT\textsubscript{i}. Therefore, required the number of transmissions and the matching table calculation proposed in section 3 is proven to validate within the proposed scheme.
Fault tolerances are shown in Figure 5. These unusual cases exceed the number of minimum transmission required compared to $\text{RT}_t$ values but the proportion is extremely low. Therefore, the average error rate is 4.1%, the minimum error rate is 2% and not over more than 6%.

![Figure 5. RT< transmission time in actual simulation case in 6 conditions(Table V)](image)

V. CONCLUSION

We have presented LTM, limited number of transmission method for QoS requirement. RTOD components for achieving reliable transfer in WSNs are discussed, implemented and tested.

The contributions of this paper are three-fold. (1) Analysis of each path reliability calculation components. (2) Verifying limited number of transmission case. (3) Propose LTM for improvement of QoS method. We extended the reliability calculation method that used only channel error rate in previous research to a process that reflects RSSI values and calculates reliability for each individual node paths and verifying with simulation.

Through performance evaluations of this method using NS-2, we can see that LTM shows less fault tolerance than not applied LTM case.

It is clarified that the proposed scheme is efficient for reliable data transfer in WSN. Our approach also opens a new method in limited number of transmission network condition, as well. In future work, we will be focus on the impact of reliability and gathering more prerequisite elements for accurate reliability.

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