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A Hybrid Approach to Reduction of Packet Loss in Wireless Sensor Network

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Abstract

Wireless sensor networks are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location The major role of sensor networks is sensing and delivering data to sink node, reliability is an important characteristic. However WSNs are associated with packet loss, which gets worse through multi-hop routing paths in wireless sensor networks, nodes near the destination have higher packet delivery performance. Numerous reasons for packet loss such as: signal attenuation due to the distance between the nodes, asymmetry in wireless communication links, non-uniform radio signal strength, wireless propagation effects (fading and multipath), interference due to hidden terminal problem, in addition to being greatly affected by the deployment environment, and the behavior of wireless communication have been noticed. In an attempt to reduce packet loss via WSN, this research study proposes a combined approach of distributed storage system algorithm for wireless sensor networks coupled with Replacing Lost Packets (Packet Loss Concealment) methods. . In an attempt to reduce packet loss via WSN, this research study proposes a combined approach of Modified distributed storage algorithm for wireless sensor networks (MDSA) coupled with Replacing Lost Packets (Packet Loss Concealment) methods. During this study, a DSS was designed with both repetition code and regeneration code in case there is a link failure. Results from this study showed that for both codes the success probability of both theory and implementation correlate, while the regeneration code showed the highest success probability. And therefore it was chosen for further study. The implementation of regeneration code results showed that the increasing of field size also correlate with the increasing of success probability for both theory and implementation. The implementation of the proposed PLC results showed that showed that the proposed PLC algorithm improves significantly the quality of speech transmitted over an unreliable network with high packet loss rate. Though, the proposed PLC introduces additional delay which needs to be considered but the increased delay is often a necessary expense if the signal quality is a priority.

Key words: Wireless Sensor Network, Distributed Storage System algorithm, packet loss concealment

1. Introduction

Wireless sensor networks (WSN) have been hampered by unreliable packet delivery. Since the major role of sensor networks is sensing and delivering data to sink node, reliability is an important characteristic. Moreover, since data from as many of the sensing nodes as possible should be delivered to the destination, fairness becomes a substantial issue. Because packet loss gets worse through multi-hop routing paths in wireless sensor networks, nodes near the destination have higher packet delivery performance. A fundamental challenge is to understand the underlying limiting factors that prevent reliability and fairness. With a comprehensive understanding, each layer can exploit the lessons learned to achieve reliable packet delivery. (Alsemairi & Younis, 2015)

There is anecdotal evidence of poor packet delivery rates from several field trials of WSN deployment. Alsemairi & Younis, (2015) show the prevalence of gray areas in which neighbor nodes receive less than half of the packets and significant asymmetry in a realistic environment. In their indoor experiments, half the links experienced more than 10% packet loss while 30% packet loss is experienced by a third of the links.

There are many reasons for packet loss. The most significant ones include: 1) signal attenuation due to the distance between the nodes, 2) asymmetry in wireless communication links, 3) non uniform radio signal strength that varies depending on the direction, 4) wireless propagation effects (fading and multipath), 5) interference due to hidden terminal problem, and gray area. Needless to say, sensor networks are greatly affected by the deployment environment, and the behavior of wireless communication is highly unpredictable under different environments. (Mohammad Hossein A.et al, 2013)

In spite of such anecdotal evidence of poor packet delivery performance, most of the designs typically assume 1) low bit error rates and consequently low packet loss, 2) 802.11-like links that avoid hidden terminal problems, and 3) generally reliable wireless communication. Even though such assumptions may become a reality in the future with advances in hardware technology, many challenges will still remain. For example, even with advances in hardware, smaller footprint devices such as today's motes are desired, despite being resource constrained.

The deployment of sensor networks in harsh environments deteriorates the quality of wireless communication. Various propagation effects and high packet loss are expected in such environments.

A way to save energy is given in (Sanam P. & Manvinder S., 2015), where the authors implement a distributed estimation algorithm, more flexible in energy-accuracy subspace and more robust than the snapshot aggregation and it also brings considerable energy savings for a typical accuracy requirement. This algorithm depends on the chosen threshold, which should be based on both the mean and the variance. In this scheme, a node broadcasts its value only if the difference between the new generated estimate for every neighbor and the old estimate is beyond that preset threshold for any of the neighboring nodes. A decentralized incremental algorithm for performing in-network optimization can be adopted to get robust estimation techniques that attempt to identify and discard bad measurements from the estimation process (Zhenzhou Tang et Al. 2012).

Another way to save energy is given in (Gungor V.C et Al.2010). Total transmission energy consumption in a sensor network, can be minimized, if quantization levels for sensors are determined jointly by the fusion center using information about correlation of sensor observation. In this paper is also given an approximate suboptimal solution to the energy minimization problem achieving the same target estimation performance as the optimal solution.

A hybrid approach would promise a reduction of packet data loss in such wireless networks. This study proposes distributed storage system for wireless sensor networks (DSS) coupled with Replacing Lost Packets (Packet Loss Concealment) methods towards packet loss reduction, as Wireless Sensor Networks, suffer from power limitation, small memory capacity, and limited processing capabilities. The rest of the paper discusses the following:

2. Proposed DSS algorithm simulation

This is aimed to simulate the proposed algorithm MDSA using well known wireless sensor network simulator called OMNET++ 4. The Factors to be considered are, such as energy consumption, number of created messages, memory usage, data recovering.

First a DSS network was designed using MatLab programming.

3. Performance evaluation of proposed DSS

After simulating the Modified distributed storage algorithm using OMNET++ 4 simulator, a numerous performance metrics were done to measure performance in each coding type. In this session we use probability to measure coding performance. The metrics used to evaluate are repletion coding and regeneration code.

3.1. Repetition Code

Replication code, we divide data in to four fragments and distributed two fragments to each storage node as shown in Figure 11. Once data collector needs to retrieve a data, it needs to connect any two nodes out of four nodes to download two fragments from each selected nodes. Somehow, four fragments that data collector have retrieve may not able to recreate original data.

In theory, we can calculate the probability that data collector can successful recreate original data as

$$P\ succ = \frac{\binom{2}{1} x \binom{2}{1}}{\binom{4}{2}} \simeq 0.67 \qquad (1)$$

This implies 67%, the original data can reconstruct back as original data.

From implementation, the number that data collector was able to successful recover a data divide by number of iteration, in this case the implement were ran out as 240 rounds. The result of implementation will be displayed how in the next section.

3.2. Regenerating Code

Path of fragments were distribute to storage node over network, after that data collector randomly select two nodes to retrieve a data. To measure a performance of network coding, we can calculate probability by using equation 9. This probability use to indicate the chances that retrieve data are success for recovers a data.

$$P_r(D_r = d) = \frac{\prod_{i=0}^{d-1}(q^{kr} - q^i)\prod_{i=0}^{d-1}(q^m - q^i)}{q^{mkr}\prod_{i=0}^{d-1}(q^d - q^i)} \tag{2}$$

where: m is number of storage node

r is amount of fragment in each storage node

k is number of node can rebuild the original at data collector

d is amount of fragment in all storage node

4. Implementation of PLC algorithm

The proposed PLC algorithm was implemented in Matlab™ environment, using Voicebox toolbox for speech processing. The LPC parameters were encoded by first converting them to reflection coefficients (RF), so that they ranged between (-1; 1) for easier quantization. A linear 7-bit quantizer was used for quantization of RF values, so the prediction coefficients filled up 18 bytes.

T0 (the pitch period in samples) occupied the next byte, ranging from 16 to 255, corresponding to F0 of 50-500 Hz. During experiments it was turn out that the most precise F0 detection was achieved using pitchdetat algorithm, so this one is to be used. For unvoiced speech T0 value will be chosen randomly, so that even if a unvoiced packet was reconstructed using excitation signal of a voiced one it was loosing its harmonicity.

E – energy parameter will be encoded using a quantizer with logarithmic characteristics and stored as the last byte of total 20 redundant ones.

5. Testing methodology of the proposed PLC

This test was done in order to verify how the proposed packet loss algorithm performs during the experiment, 24 semantically unpredictable sentences (SUS) were recorded, by a male and female speaker. They were transmitted through software packet network simulator at different packet loss rate (0-35%), using Gillbert-Elliott model of packet loss . For a given PLR the same pattern of loss packets was maintained when testing all PLC methods. Two different PLC variants were used:

- no PLC algorithm at all;
- Lost packets reconstructed by the proposed PLC algorithm.

The reconstructed signal was recorded, thus forming 2 sets of output speech signal, henceforth called: no PLC, and proposed PLC. Test performed are:

ACR is a subjective method which can be used for assessment of speech quality; among others it can be used for testing VoIP transmission quality. It requires participation of listeners who assess the output speech quality, assigning scores on a 5-degree MOS (Mean Opinion Score) scale ranging from very bad to excellent.

SUS method of intelligibility testing consists in transmitting nonsense (semantically unpredictable) sentences through a telecommunication channel. In this test, Listeners also need to participate in this test – they are asked to write down the sentence as they can hear it. Due to lack of sense in SUS sentences, they are able to correctly note them only if the speech is intelligible enough.

6. Results and Discussion

6.1. Performance Metrics of proposed DSS

6.1.1. Comparison of Success Probability between Repetition and Regenerating codes

The figure 4.4 illustrates the results of comparison between Repetition and Regenerating codes in the same field.

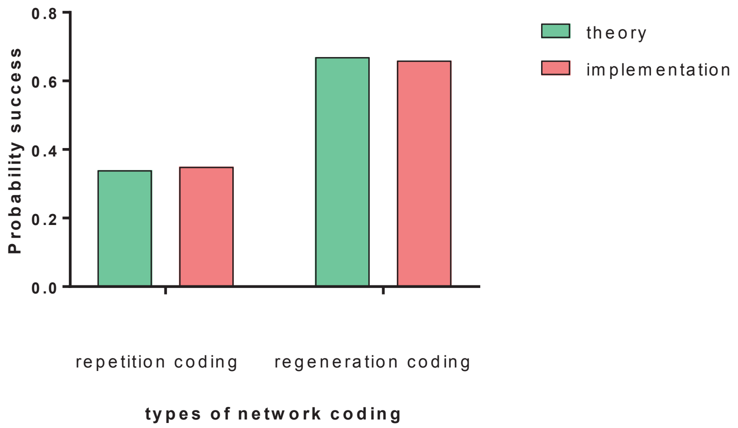

Figure 1: Comparison of success probability of regeneration code between implementation and theory

From result in Figure 4.4, result shows that implementation correlate with theory result. It shows that regenerating coding has better performance for recover original data back. Effect of field size will show in the next session.

6.2. Result of Implementation Regenerating code

In this path, we have done our implementation on our test bed. Original data is dividing in to four fragments then encode and distributed to four storage nodes. On our test bed, success probability count from a successful recovers original data from two random selected storage nodes. At the end, there were variation of field size to see the effect of field size to success probability. The figure 4.5 illustrates the results from this performance.

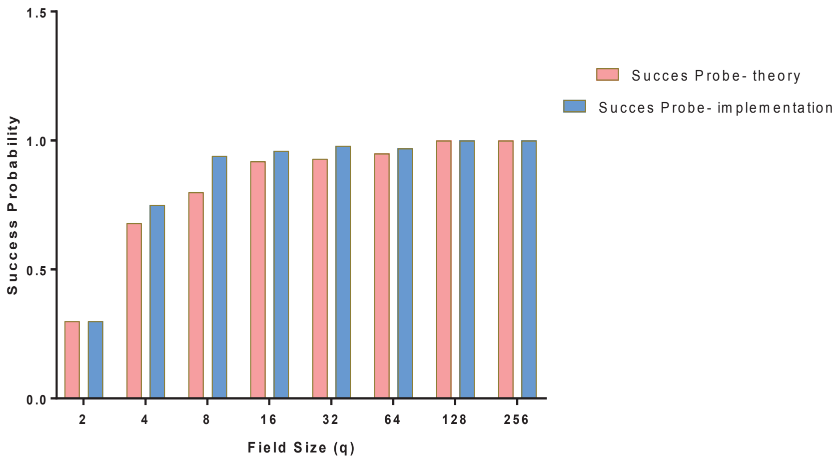

Figure 2: Comparison Success Probability of Regenerating Code between implementation and theory

Results shows that when increasing filed side in term of power of 2. A probability of success rate is increasing and approaches one as a field size increase. And from implementation, it also show a same trend as theory shows. Its imply implementation result correlate with theory result.

6.3. Results of implementation of proposed PLC

As mentioned in 3.4.3 the PLC proposed was implemented in a predesigned DSS. 48 subjects took part in SUS and ACR tests; they were exposed to 576 recordings (24 SUS sentences x 8 PLR values x 2 PLC algorithms) ACR methods result in MOS score (0.5 - 4.5), while intelligibility tests result in percentage of correctly conveyed sentences and words. This section shows the results of both ACR and SUS tests.

6.4. MOS Results for the proposed PLC

The figure 4.5 shows the results of MOS (Mean Opinion Score) for packet loss rates (PLR) values using Absolute Category Rating (ACR) method.

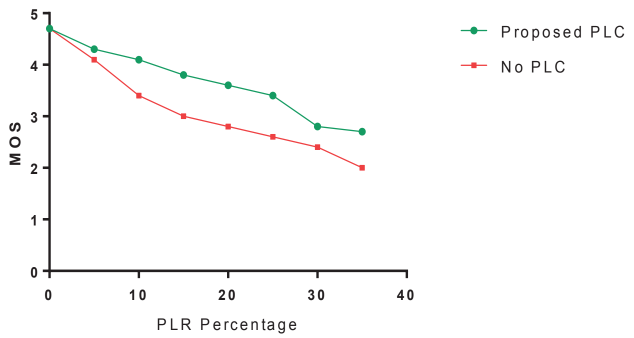

Figure 3 MOS results for different PLR values using ACR method

6.5. Word intelligibility test

SUS method of intelligibility testing was performed to assess speech quality, the figure 4.6 stands for the results from this test.

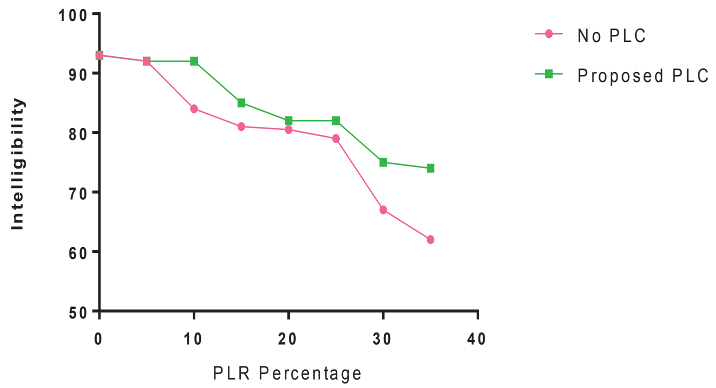

Figure 4: Word intelligibility from SUS test

6.6. Sentence intelligibility results

The sentence intelligibility results are depicted in the figure 4.6

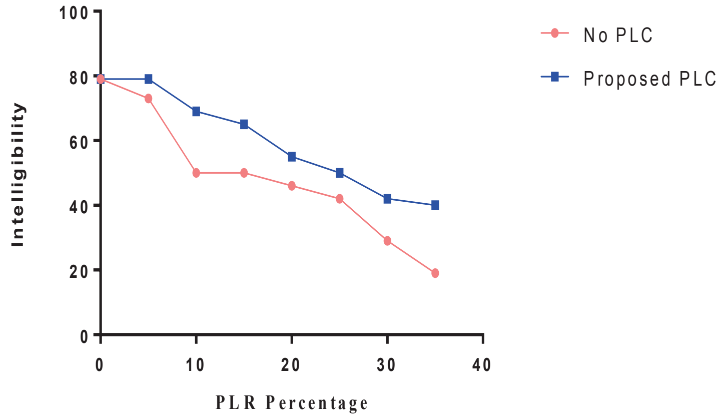

Figure 5: Sentence intelligibility results from SUS test

7. Discussion

Figure 1 shows the comparison of success probability of regeneration code between implementation and theory. From the results, it has been observed that regeneration coding has better performance for recover original data back. Additionally, both repetition and replication code show that implementation correlate with theory result. Similar results were reported by (Chareonvisal, 2012) where he observed the correlation between success probability of both theory and implementation.

The results from Implementation Regenerating code shows that when increasing filed side in term of power of 2. A probability of success rate is increasing and approaches one as a field size increase. And from implementation, it also show a same trend for theory results. This implies the correlation of both implementation result and theory results. The same results were echoed by (Chareonvisal, 2012) in his report "Implementing Distributed Storage System by Network Coding in Presence of Link Failure", stating that the increasing of field size does not affect the probability success.

The implementation of the PLC algorithm proposed into predesigned DSS was done. The figure 3 which shows the results of MOS (Mean Opinion Score) for packet loss rates (PLR) values using Absolute Category Rating (ACR) method. The results shows that the MOS for proposed PLC is higher compared to that observed when no PLC was employed. This results is similar to the results reported by Janicki et al. (2006) in where PLC they proposed was showing higher results.

The word intelligibility test using SUS test as depicted in figure 4 showed that when PLC was used the word displayed could be received at highest level compared the situation where no PLC was used. The results are similar to those observed when sentence were displayed as shown by the figure 5. Janicki et al. (2006) report that the results of quality and intelligibility tests showed that the proposed PLC algorithm improves significantly the quality of speech transmitted over an unreliable network with high packet loss rate. It performs also better than a receiver-based ANSI T1.521a Annex B algorithm; however, they said that their proposed PLC introduces additional delay which needs to be considered with a conclusion that an increased delay is often a necessary expense if the signal quality is a priority.

7. Conclusion

This study had for objective to develop a hybrid approach towards the reduction of packet loss in wireless sensor networks. Which were developed from a designing an algorithm for distributed storage systems (DSS), into which another developed PLC algorithm was implemented. From the results of the study we can conclude that data sent via WSN comprising the proposed hybrid approach once lost can be recovered and hence improve the data loss recovery. However even though the results showed a promise with this approach so much work is still needed to be done in order to make the approach proposed more effective.

References

A. Janicki, B. KsięŜak, J. Kijewski, and S. Kula, (2006) "Speech quality assessment in the Internet telephony using semantically unpredictable sentences" (in Polish), Przegląd Telekomunikacyjny i Wiadomości Telekomunikacyjne 8- 9/2006, Warsaw.

Alsemairi, S. and Younis, M. (2015) "Adaptive packet-combining to counter traffic analysis in Wireless Sensor Networks" Wireless Communications and Mobile Computing Conference (IWCMC), 2015 International

Mohammad Hossein Anisi, Abdul Hanan Abdullah, Yahaya Coulibaly, Shukor Abd Razak, (2013). "EDR: efficient data routing in wireless sensor networks" International Journal of Ad Hoc and Ubiquitous Computing, Volume 12, No 1, 2013

Sanam Preet Kaur, Manvinder Sharma, (2015). "Radially Optimized Zone-Divided Energy-Aware Wireless Sensor Networks (WSN) Protocol Using BA (Bat Algorithm)", IETE Journal of Research Volume 61, Issue 2,

Zhenzhou Tang, Hongyu Wang, Qian Hu, and Long Hai, (2012). "How Network Coding Benefits Converge-Cast in Wireless Sensor Networks", In Proc IEEE Vehicular Technology Conference (VTC 2012 Fall).

Gungor, V.C. , Bahcesehir; Bin Lu ; Hancke, G.P. (2010). "Opportunities and Challenges of Wireless Sensor Networks in Smart Grid Industrial Electronics", IEEE ..Volume:57 Issue:10

Tanakorn Chareonvisal, (17 September 2012) "master thesis report Implementing Distributed Storage System by Network Coding in Presence of Link Failure" School of Electrical Engineering Kungliga Tekniska Högskolan Stockholm, Sweden

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