J. Basic. Appl. Sci. Res., 2(5)4880-4885, 2012
© 2012, TextRoad Publication
ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

New Active Caching Method to Guarantee Desired Communication Reliability in Wireless Sensor Networks

Amir Shiri [1], Shahram Babaie [2], Javad Hasan-zadeh[3]

[1,2,3] Department of Computer Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran

ABSTRACT

Wireless sensor networks (WSNs) consist of large number of sensor nodes which are capable to sensing different environmental phenomena and sending the collected information to the base station which is called Sink. Since the sensors are made of cheap components and are deployed in out of hand and uncontrolled environments, they are prone to have faults; so maintaining the network in proper functionality despite undesired events seems to be necessary which is called fault tolerance. Generally every wireless sensor network requires a certain level of communication reliability depending on data recovery mechanism and re-transmitting the lost packets. In this paper we will propose a method for recovering lost packets by caching data in some of network nodes which is a combination of Extended NACK and Active Caching (AC) methods and we call it New Active Caching (NAC). Simulation results show that proposed method increases communication reliability level and fault tolerance in wireless sensor networks.
Keywords: Wireless Sensor Network; Fault tolerance; Packet loss; Caching; Information Recovery.

INTRODUCTION

Recent developments in the field of micro-electro-mechanic systems, wireless communication and digital electronics have simplified developing cheap, low consumption and tiny sensors which are capable of multi task monitoring and communication functions in uncontrolled environments. These tiny sensors are able to sense, process data and transmit information to the sink [1]. Each sensor node communicates with the other sensor nodes by its radio transceiver. A WSN can be configured as either single hop or multi hop. In a multi hop sensor network a pair of sensor nodes may be located outside of their transmission ranges and hence be unable to communicate directly. In a single hop sensor network each sensor node is able to communicate directly with all the other sensor nodes [2]. As a result the multi hop networks require routing protocols [3] but the single hop networks don't [4,5]. Application of WSNs include: Environmental monitoring, military and security, agriculture and ranching, health care and etc [6,7].

Current methods for information recovery within the packet lost occurrence in WSNs are divided into two methods: end to end loss recovery (E2E) and hop by hop loss recovery (HBH). In these mechanisms when a packet is lost, re-transmission of data is done by source or middle nodes. In HBH method data packets are stored in the memory of the all middle nodes. In this method, if packet loss occurs in transmission, a re-transmission request will be sent back to previous node and that node based on the restored data in its memory re-transmits the same packet. In E2E method as soon as the destination node receives incorrect packet, re-transmission request will be sent back to the source node, So that the source node will have to send the same packet again. As a result the required memory in HBH method is higher compared to E2E method but delay is less [8].

PSFQ [8] and RMST [9] are two common protocols of HBH method. PSFQ protocol is a data transmission protocol based on ACK message which uses HBH mechanism in packet recovery and multicasting method in packet transmission. Reliability level in this protocol is high unless the entire packet is lost. RMST protocol is a data transmission protocol based on NACK messages which uses HBH mechanism for packet recovery and uses uni-casting method for packet transferring. In this method reliability level is also high as well, unless the data packet loss entirely. In this protocol with the transmission of NACK message to the previous node the loss of packet is determined and the receiving node is responsible for data recovery control.

Active caching approach [10] is able to make the network tolerant against destructive factors which cause packet loss. Thus in this paper we will propose a new method that is combination of Active Caching and Extended NACK [11] which is expected to demonstrate better results in comparison with these methods.

The rest of paper is organized as follows: section 2 discusses related works in the area of increasing fault tolerance and reliability in WSN, a detailed description of the proposed method is presented in section 3, also evaluation and simulation results are shown in section 4, finally, the paper is concluded in section 5.

RELATED WORK

Several methods have been proposed to increase the reliability level and fault tolerance in WSNs [7]; Active Caching [10] and Extended NACK [11] being the most common which are discussed as follows briefly.

***Corresponding Author:** Shahram Babaie, Babaie's home appliance, opposite behdasht, Kashani street, Maragheh.Iran.
E-mail:hw.tab.au@gmail.com Tel/Fax/Mob:0098914

A. Using Active Caching method to increase the fault tolerance

In this method data will transfer from source to destination HBH. In this case a number of middle nodes store the received packets in their memories so they can re-transfer the packets when the packets are lost in the next hops and a request is received stating lost packet occurrence; as a result there is no need for the source node to re-transmit the data. Using this technique network traffic and the energy consumed in nodes will be decrease and the lifetime of the network will be increase. Figure 1 shows a imaginary path in a WSN with five nodes. In the aforementioned path the reliability of each connection is 95%, meaning that the possibility of packet loss is 5%.we suppose that the required reliability between source node and the sink is 85%.

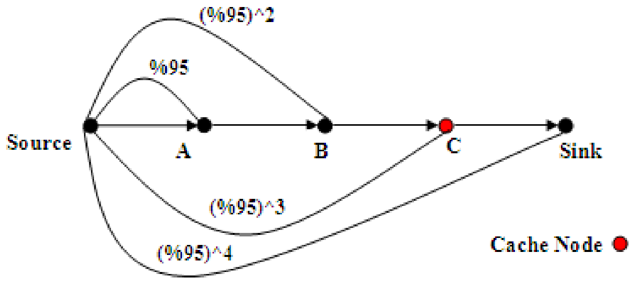


Figure 1: Imaginary path with 5 nodes.

By considering above probabilities we will have:

- The possibility that sent data from source node is received correctly by node A is 95%.
- The possibility that sent data from source node is received correctly by node B is (95%) ^ 2 = 0.9025.
- The possibility that sent data from source node is received correctly by node C is (95%) ^ 3 = 0.8573.
- The possibility that sent data from source node is received correctly by sink is (95%) ^ 4 = 0.8145

Hence if data is sent HBH from source to sink, the data will be received by sink with the probability of 0.8145 which is less than the expected reliability of 85%. Therefore it is necessary to achieve the expected reliability by the appropriate approach. In Active Caching method data is stored in node C so in case of packet loss there will be no need to re-transmit them form source node. In case of re-transmission by source node, nodes A, B and C consume more energy as communication interfaces.

With this simple approach middle nodes consume less energy and if necessary, the lost packet will be re-transmitted to sink from node C, the possibility that the data is sent correctly from node C to the sink is 95%. Data will be received by sink with the probability of 95% from source, which is higher than the expected probability of 85%. Figure 2 represents the pseudo code of algorithm.

```
RELIABLE−TRANSMIT(CR, i, pi, Ptx(i−1), F(i−1))

Ptx[i] ← Ptx[i − 1] · (1 − pi)
if Ptx[i] > CR
   then F[i] ← false
   else F[i] ← true
        Ptx[i] ← (1 − pi)
        cache data packets to a node ni
```

Figure2: Active Caching algorithm pseudo code [10].

Important issue in Active Caching method is that when a packet is lost in middle nodes, a NACK message will be sent back to previous node. Therefore NACK message will be sent as the same number of hops between the node not receiving the packet correctly and source node, so that the NACK message will be received by the node which data cached in it. For instance in figure1, node C and source node are assumed to be caching nodes to increase the reliability. Now let's assume that a packet is lost before being received by node C, in which case NACK message will be sent three times, the same number of hops between node C and source node. Source node re-transmits the packet as soon as it receives NACK message.

B. Using Extended NACK method

Other than the Active Caching method which uses storing packets in middle nodes to increase reliability level, there is another method which is called Extended NACK method, which tries to eliminate the over use of NACK message to increase the reliability of the network. As a result the lifetime of network will be increased by eliminating the over use of control packets. The function of this method focused on the general basis which indicates that the data transferring based on multi-casting in WSNs, so whenever a node receives a packet it will re-transmit the packet to all the neighbor nodes. Thus this packet will be transmitted to the nodes that are closed to the sink and also will be transmitted to previous node which has sent this packet to this node. As a result if a packet is received by a node that itself was send it a few moments ago, the node will conclude that the packet is transferred to next node correctly. If the transmitted packet does not receive again in a certain time, a packet loss can be concluded in recent transmit process. Hence with a simple approach, without the need for ACK and NACK messages, we can make sure that the packet is received by next node or not.

Main flaw of this method is that when a node which is not a caching node, infers that the packet is not received by next node; it will have to send the NACK massage to previous node. Consequently a certain number of NACK messages are required so that the source node infers the packet loss and re-transmits it. Hence it can be presumed that combining this method and Active Caching method can make the network tolerant against deficiency and packet loss.

The same approach can be stated in figure1; when a packet is sent by source node, passing several nodes HBH, the sink will receive the packet. When node B sends the packet to node C, node C will transmit the packet to node B. If packet loss occurs while transmission by destructive environmental factors, node B will not receive the packet again and it will infer the loss of packet and will transmit a NACK message to node A and node A will send the message back to the source node respectively. In this imaginary network number of NACK messages is taken two. Now if the same approach is applied in a long path; it is obvious that the number of NACK messages will be more than two, so the node, being the source node in this example, which is able to re-transmit the packet will deduce the packet loss and do the task of re-transmission.

PROPOSED NEW APPROACH FOR INCREASING FAULT TOLERANCE

The proposed approach is combination of Active Caching and Extended NACK approaches. In order to increase the reliability in Extended NACK approach some of the nodes are considered as caching nodes. Figure 3 illustrates an imaginary network with eight nodes. In this network both C & F nodes are taken as caching nodes. Packets were sent by source node will reach the sink HBH based on multicasting method. Assuming that transmitted packet by source node has successfully reached node E. Node E will transmit the packet so it can reach the sink through node F. If node E does not receive the transmitted packet again in a certain time, it will infer as node F has not received the packet and packet loss has occurred and it will send a NACK message to node D consequently and node D will send the same NACK message to caching node C. After receiving the NACK message by caching node C, this node will re-transmit the packet. In the aforementioned imaginary network the number of transmitted NACK messages for Active Caching and Extended NACK approaches are three and five respectively, whereas the number of NACK messages is reduced to two using the proposed approach. As a result the proposed approach seems to be optimized in factors such as delay in packet transmission, number of transferred packets and energy consumption.

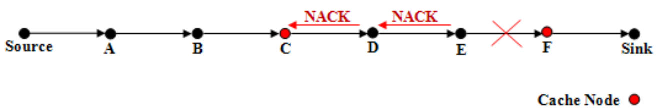


Figure 3. assumed path with eight nodes.

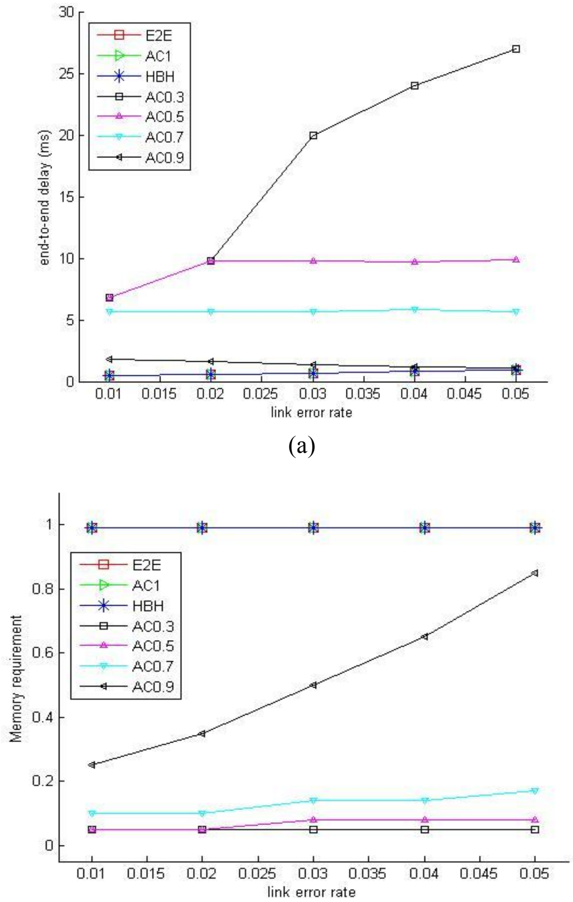
SIMULATION AND EVALUATION

In order to evaluation performance of the proposed method, it is compared to AC approach in factors such as delay of packet transmission in number of packet loss occurrence, packet transmit rate and energy consumption. Simulations are done using MATLAB software and the simulations parameters are given in table 1.

Table 1. simulation parameters.

Parameter	Value
consumed energy to transfer a NACK packet	4 nj/packet
consumed energy to transfer a data packet	25 nj/ packet
NACK packet size	4 bytes
Data packet size	25 bytes
Data transmission rate	210 kbps
Number of sensors	20
required time to transfer a NACK packet	4 ms
required time to transfer a data packet	25 ms

AC with communication reliability from 0.1 to 1 is expressed as AC0.1 to AC1. Figure 4 illustrates the comparison of performance E2E, HBH and AC approaches. Since the AC method with highest memory requirement stores data in middle nodes, it acts as HBH approach; but it will act as E2E method whenever it does not perform data caching. In other words AC method switches between E2E and HBH approaches and illustrates the performance tradeoff between them. Figure 4(a) displays E2E delays of different approaches with the varying link error rate. As it is shown in the figure the AC approach has more end-to-end delays in comparison with E2E approach. Among AC approaches the AC0.3 method, which considers 30% of the nodes as caching nodes, has the most delay. Figure 4(b) displays the memory consumption of different methods. AC approaches are seen to have highest memory consumption. Figure 5 displays the ratio of caching nodes to all the network nodes. As it was shown in previous figures the AC method increases the reliability of the network considerably. To investigate the efficiency of the proposed approach it is compared with AC method. Several evaluation parameters have been used which are further discussed in this paper.



(a)

(b)

Figure 4. Performance Comparison of E2E, HBH and AC methods [10].

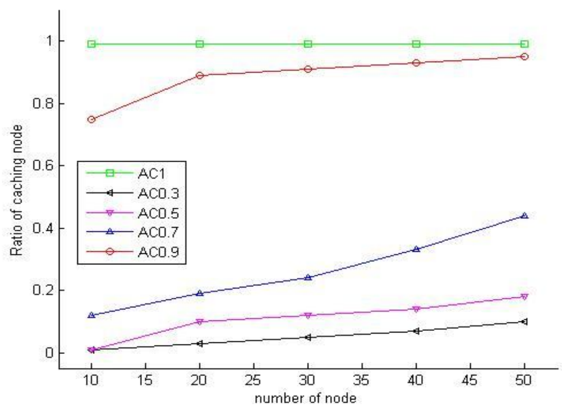


Figure 5. The ratio of caching nodes [10].

C. *delay of packet transmission*

To calculate the transferring delay it is assumed that a packet is lost among the caching nodes. In this case in AC method NACK message will be sent from the node which was unable to receive the packet correctly and the number of NACK messages is equal to the number of hops amongst nodes from the node being unable to receive the packet to cache or source node. In proposed approach the number of NACK messages sent is one message less than the AC approach. In the simulation process the time needed to transmit the NACK packet from one node to another is assumed to be 4ms. Since the number of NACK messages in proposed approach is one message less than AC approach, every time a packet is lost among the caching nodes, the re-transmitted packet reaches the destination 4ms earlier. In case a packet loss does not occur among caching nodes and it safely travels through middle node to reach the sink, the arrival time to destination is 19*25ms for both approaches. As it is displayed in figure 6 whenever a certain packet is lost eight times in the network, in proposed approach the re-transmitted packet reaches to destination 32ms earlier in comparison to AC approach.

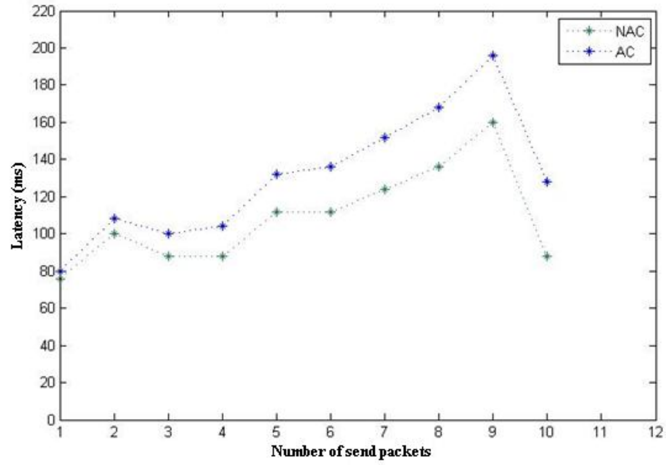


Figure 6. delay in Active caching and proposed approach.

D. *Calculation of number of transmitted packets*

Since the number of NACK messages in proposed approach is one message less than the AC approach, every time a packet is lost among the caching nodes, in proposed approach one packet lesser will be sent in comparison to AC approach. As the number of a certain packet lost in the process increases; for instance the packet is lost for *n*th time, in the proposed approach *n* packet will be sent less than of the AC approach. As it is displayed in figure 7 whenever a certain packet is lost eight times in the network, in proposed approach eight packets are sent less than of the AC approach.

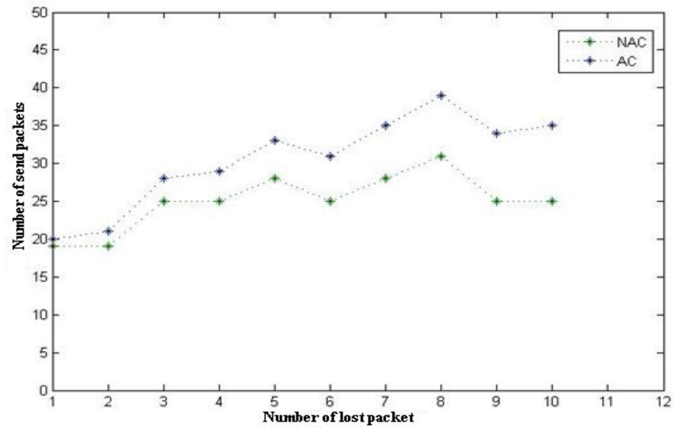


Figure 7. number of transmitted packet in active caching and proposed approach.

E. *Calculation of energy consumption*

According to table 1 the energy required to transfer a NACK messages from one node to another is 4nj. Since the number of NACK messages in proposed approach is one message less than the AC approach, in addition to packet transmit delay decrease, the amount of energy consumed in proposed approach decreases in comparison with AC approach. As it is shown in figure 8 if the certain packet is lost for eight times in the network the proposed approach consumes 32nj less in energy comparison with AC approach.

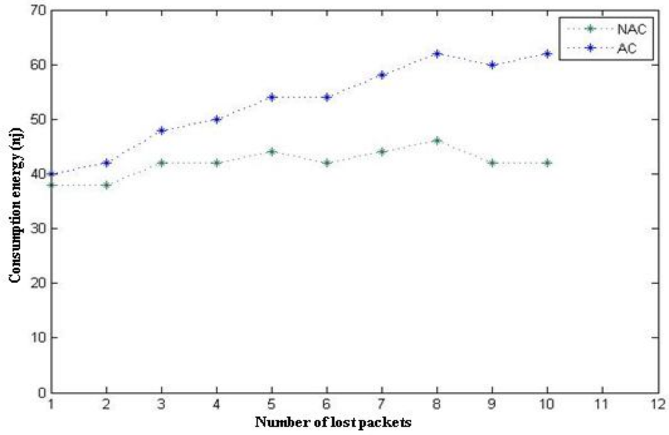


Figure 8. energy consumption in AC and proposed approaches.

CONCLUSION

The necessity for fault tolerance in wireless sensor networks was discussed in this paper. Further the common methods used to recover information in case of packet loss in WSNs, being E2E and HBH methods, were analyzed and the performance of Active caching and Extended NACK methods were studied. The results of the study indicate that AC method shows a better performance in comparison to previous methods, hence in this paper a new approach which tries to reduce the number of NACK message and increases the lifetime of the network was proposed. The proposed approach which is called NAC was compared with AC method. Results of the simulations indicate that the proposed approach in parameters such as transfer delay of packets, number of transmitted packets and energy consumption demonstrates better performance. Review the number of nodes used for caching and the order of placing them will be our future work.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A Survey on Sensor Networks," IEEE Communications Magazine, Vol.40,No.8, pp.102-116, August 2002.

[2] S. Chessa and P. Maestrini, "Fault recovery mechanism in single-hop sensor networks," January 2005 Elsevier.

[3] B. karp and H.T. Kung, "Greedy perimeter stateless routing (gpsr) for wireless networks," 2000 IEEE.

[4] M. Singh and V. K. Prasanna, "Optimal energy-balanced algorithm for selection in a single-hop sensor network," May 2003 IEEE.

[5] M. Singh and V. K. Prasanna, "Energy-optimal and energy-balanced sorting in a single-hop sensor network," March 2003 IEEE.

[6] D. Culler, D. Estrin, and M. Srivastava, "Overview of sensor network," Computer(Long Beach, CA), vol. 37, no. 8, pp. 41-49, 2004.

[7] F. Koushanfar, M. Potkonjak, and A. Sangiovanni-Vincentalli, "Fault Tolerance Techniques for Wireless Ad Hoc Sensor Networks," 2000.

[8] C. Y. Wan, A. T. Campbell, and L. Krishnamurthy, "PSFQ: a reliable transport protocol for wireless sensor networks," in proc. ACM International Workshop on Wireless Sensor Networks and Applications, pp.1-11, Sept. 2002.

[9] F. Stann and J. Heidemann, "RMST: reliable data transport in sensor networks," in Proc. IEEE International Workshop on Wireless Sensor Networks and Applications, pp. 102-112, May 2003.

[10] D. Y. Kim and J. Cho, "Active Caching: A Transmission Method to Guarantee Desired Communication Reliability in Wireless Sensor Networks," 2009 IEEE.

[11] L. C. Zhong and G. Cho, "an nttgrated data-link Energy Model for Wireless Sensor Networks," 2007 IEEE.