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# A New Approach for Wireless Sensor Network Lifetime Maximization and Low Overhead with Hybrid ARQ (HARQ) Error Control Protocol

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**ABSTRACT**

The deployment of high densities of node due to the advancement in Wireless Sensor Network (WSN) technology had created the concern regarding the lifetime and error presented in the network. From the previous studies, Hybrid ARQ (HARQ) error control techniques can combat errors and indirectly, can reduce the energy consumption of sensor nodes. Based on the latest previous work, the HARQ algorithm were not able to combat the issue of interference properly. Not to mention, the implementation of Error Correcting Codes (ECC) in the module of HARQ on the unconducive environment will cause additional overhead. Thus,the problem regarding the interference and overhead in WSN becomes our motivation to research HARQ error control protocol with for lifetime maximization and less overhead WSN by implementing along the Kalman Filter algorithm for channel state estimation. This research proposes the low overhead HARQ error control algorithm for lifetime maximization in terms of node densities and packet sizes. This research is expected to show that the proposed HARQ algorithm can lower the overhead and maximize the lifetime of WSN by means of lowering the error rates and interference levels.



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## INTRODUCTION

The advancement and modernization of wireless technologies had put the Wireless Sensor Network (WSN) usage to the maximum utilization in many kind of applications such as habitat monitoring, agricultural, military and health sensing (Bokare & Ralegaonkar, 2012)(Othmana & Shazalib, 2012)(Tung, Ly, & Binh, 2015)(Yang, 2014)(Ecosensa, 2011). WSN consists of autonomous sensors that monitor the environment in a monitoring field. The data was sent from the specific sensors and passed to the sink or Base station (BS). As the wireless sensor network deployed wireless adhoc communication, there will be risen issues in terms of interferences, errors and lifetime. The heavy and large data transmissions in adhoc wireless sensor network had concern many researchers on the aspects of energy-constraint and error rates in the network. The error prone network might vulnerable to attack such as Denial of Service (DOS) and spoofing that might lead to data loss and cause the unavailability to the company(Anwar, Bakhtiari, Zainal, Abdullah, & Qureshi, 2014). Thus, many techniques and methods are urged to be found and studied to combat the major issues of lifetime of the network and erroneous in transmissions. Not to mention, the high computation (Sen, 2010) and communication overhead (Kori & Baghel, 2013) that due to the security features and increase in the length of the network had also cause serious critical usage of energy.There are many techniques to enhance the lifetime as well as reducingthe overheads in WSN that can cause serious reduction of lifetime. One of the techniques to be highlighted is Hybrid ARQ Error Control Protocol. This technique is by combination of ARQ and FEC. ARQ is one type of error control protocol in which the sender will keep retransmitting the packet if the sender did not get the acknowledgement (ACK) packet by the receiver. On the other hand, the ARQ might flood the network with retransmission if there are high error rates or packet drops in the network. There are three type of ARQ protocols such as Stop-and-wait ARQ, Go-Back-N ARQ, and Selective Repeat ARQ. FEC on the other hand does not apply the retransmission strategy. The sender does not have to retransmit error packets and the receiver can correct the erroneous packet itself. ARQ and FEC implementation alone had been demonstrated causing too many drawbacks

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in WSN. For example, the ARQ might be a simple error control that has less overhead impact. However, ARQ implement retransmitting strategy that can reduce the lifetime of WSN (Alrajeh, Marwat, Shams, & Shah, 2015). FEC also have been implementing the Error Correcting Codes (ECC) that could increase the encoding and decoding overhead. And, usually, the decoding overhead consumes much significant energy. HARQ by (Uma Datta & Kundu, 2014) and by most previous research had demonstrated the degrade in energy consumption. However, according to the work of Uma Datta and Kundu (2014), the HARQ algorithm might not tolerated with high interference levels in the high density of nodes. The HARQ might not have a very high overhead compared to ARQ or FEC, however, the improper Error Correcting Codes (ECC) usage in condensed network might result in redundancy (Eriksson, 2011) and high decoding overhead that might further degrade the lifetime. From most of previous research, the Kalman Filter had proved as the best estimator for RSSI and can track the channel state properly(Masood, Ahmed, & Khan, 2012). Based on the study of Kalman Filtering, the Kalman Filter algorithm can be a key to produce the accurate estimate to predict the future transmission and reduce unnecessary high level of interference. Thus, this paper propose the new approach in extending the lifetime of WSN by means of reducing error rates, interference levels and possible overheads in WSN with the Kalman Filtering and proper usage of ECC. The remainder of the paper is organized as follows: In section 2, related works regarding HARQ are explained briefly. Section 3 presents the methods that will be used for the proposed framework of HARQ algorithm and Kalman Filter based algorithm. Expected results will be justified in Section 4. Finally, section 5 concludes the paper and section 6 explained on the Future works.

## 2. *Related Work:*

The related work had been reviewed in order to determine the best and suitable methods to be studied in terms of lifetime maximization, error mitigation, interferences reduction and overheads reduction.

### *2.1. HARQ:*

The common previous works regarding the expanding the lifetime of the WSN are highlighting on the error control schemes such as ARQ, FEC and HARQ. Over the years of research on ARQ and FEC, the implementation on these two protocols alone might foster some overheads. ARQ creates retransmission in the network in which the transmitter will keep resending the dropped packet due to errors until the packets are successfully received by receiver. The retransmissions in the network will prolong the delay and will use more energy. This will lead to reduction in the lifetime of WSN. FEC on the other hand, had some advantages over ARQ in terms of using less energy. However, the implementation of FEC creates more complexity and in some cases can consume more energy.(Manzoor *et al.*, 2013) HARQ is the conventional combination between ARQ and FEC could reduce the overheads. In HARQ, a transmitter might have FEC encoded packet that can correct errors besides detecting them. If the FEC cannot correct errors, ARQ will take the role to retransmit the error packet.

The latest modification on HARQ was by (Uma Datta & Kundu, 2014). From these studies, HARQ being proposed as the promising error control schemes for WSN in a condition of high level interference and high densities of node. Based on their work, hop-to-hop ARQ consumes less energy than HARQ-I at the lower node densities only. They explained that the HARQ-I with high error correcting capabilities consume less energy than ARQ when the node densities started to rise. This proved that HARQ can extend the lifetime by mitigating errors. However, in their research, the authors had not solved the interference problem as the present of high interference level might affect BER. From other studies, implementing the HARQ alone can combat some overhead that were carried by FEC error protocol. (Wei, Mao, Leng, & Huang, 2014)

### *2.2. Error Correcting Codes (ECC):*

Error Correcting Codes is the module that being applied in FEC error control protocol in which this ECC add the redundancy to the packet to increase the performance of error control. There are two type of ECC such as block codes and convolutional codes. These two types of ECCs give different performance and error correcting capabilities in the different kind network environment.

### *2.3. Kalman Filter:*

Kalman Filter is an algorithm or also known as Linear Quadratic Estimation (LQE) which act as estimator or predictor for a certain applications such as signal processing, image processing and others. In addition, Kalman Filter operates recursively on streams of noisy input data to optimally estimate the system state. Kalman Filter can estimate the channel state or future RSSI for transmissions. Kalman Filter usually uses a series of measurements observed over time, containing noise and other inaccuracies in order to produce estimates. The Kalman Filter algorithm has two stages which are prediction and measurement update stages. (Faragher, 2012)

## 3. *Methods:*

Section 3.1 will shows the summarization of overall methodology used while Section 3.2, Section 3.3 and Section 3.4 explained the block diagrams for the proposed methodology in details such as HARQ algorithm model from previous work, Kalman-Filter algorithm and the proposed HARQ and Kalman

Filter algorithm respectively. This research work proposes the implementation of the HARQ algorithm with the modification on extending the lifetime with lowering the interference and overhead without compromising error rates. The parameters that will be tested are the node densities and packet sizes that shown in Table 1. While, the performance metrics that will be evaluated are interference levels, overhead and error rates.

### *3.1. Proposed Methodology:*

Fig. 1 shows the overall methodology that will be carried out in creating the models and framework.

The methods will be carried out using Ns-2 version 2.35 and Matlab R2013a. The simulator is preferred because of inefficiency of instruments as this research will be using high node densities. The simulator Ns-2 provide the capabilities for researchers to configure in details the network topologies, nodes, protocols and aided with various modification or contributed codes.+

The figure 1 shows the overall proposed methodology initiated for the research. Based on the figure 1 below, the research will be initiated by creating the scenarios into groups. The scenarios will be created depending on the parameters and will be configured accordingly to the common motes (i.e, MicaZ) in the aspect of initial energy, propagation as shown in table 1. The parameters as specified in table 2 were adapted by the work of (Uma Datta & Kundu, 2014) and also cooperated the different packet sizes in order to study the effect of packets to the error rates, interference levels and overhead in the network based on the proposed algorithm. The parameters are being adapted in order to evaluate the effectiveness of proposed algorithm from the previous work.The existing HARQ algorithm will be created following the existing architecture of HARQ-I without the estimation of RSSI and channel states. The detail of the design on HARQ algorithm will be explained in the Section 3.2. Then, this existing HARQ will be simulated with the scenarios generated to get the initial data. This initial data will be compared with the proposed algorithm to evaluate the effectiveness of Kalman Filter estimation. After the initial results have been obtained, the Kalman Filter algorithm will be used to estimate the channel states for future transmissions. The detail on the Kalman Filtering will be explained in the Section 3.3. The existing HARQ will be optimized with the predicted values. Next, the suitable ECC will be determined to get the low overhead algorithm without compromising interference levels, lifetime and error rates. The detail on the optimization of proposed HARQ algorithm with the Kalman filtering estimation and suitable ECC will be explained in the Section 3.4. Finally, the proposed algorithm will be compared with the previous work, and existing HARQ-I.

### *3.2. Design of HARQ algorithm:*

The methods are separated into three steps:

Step 1: The HARQ algorithm will be designed and implemented in the WSN using the sample data sets to measure the initial state and effectiveness of the algorithm in the network. The block diagram in Fig. 2 shows the block diagram in Step 1.

The equation (1) shows the energy efficiency expression that was used in corresponding to CDMA network. (U. Datta, Sen, & Kundu, 2011)work on HARQ-II had specified the equation (1) of energy efficiency with the addition in BCH encoding to expression. In this research, the formula in (1) will be replicated to study the existing architecture of previous work corresponding to this research later on.

$$\varepsilon_{HARQ-II} = \frac{E^{eff}}{E_{avgHARQ-II}}\left(1 - PER_{HARQ-II}\right) \quad (1)$$

Where,

$E^{eff}$ = Effective energy consumed by the message

$E_{avgHARQ-II}$ = average energy consumption for successful delivery of message

$PER_{HARQ-II}$ = Packet Error rate of HARQ-II

The formulae will be derived by both work of (U. Datta *et al*., 2011)(Uma Datta & Kundu, 2014) for the evaluation on the existing scheme. As being mentioned in Section 3.1, the existing algorithm will be simulated inside the created scenarios to obtain initial result for further comparisons.

### *3.3. Estimation on Channel States with KalmanFiltering:*

Step 2: The channel states and RSSI will be estimated for future transmissions.

The idea of estimating the channel states and RSSI is in aspects of transmission power. The good channel state and RSSI does not need the high transmissionpower. Thus this will automatically save more energy and the low overhead ECC can be determine in the next step corresponding to the channel states.

The equation in (2) and (3) show the equations of Kalman Filter based on(Faragher, 2012)(Welch & Bishop, 2006).

$$x_k = Ax_{k-1} + Bu_{k-1} + w_{k-1} \quad (2)$$

$$z_k = Hx_k + v_k \quad (3)$$

Where,

A = state transition model which is applied to the previous state$x_{k-1}$

B = control-input model which is applied to the control vector$u_{k-1}$

w = process noise

$Hx_k$ = observation model which maps the true state space into the observed space and $v_k$

These two equations will be used to estimate the future RSSI and channel states for future transmission. The estimation of the system state will help the algorithm to initialize and prepare the network before the transmissions. Moreover, the

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predicted values will be used for determining proper ECC that suitable for the network environment to reduce potential communication and traffic overheads that rises.

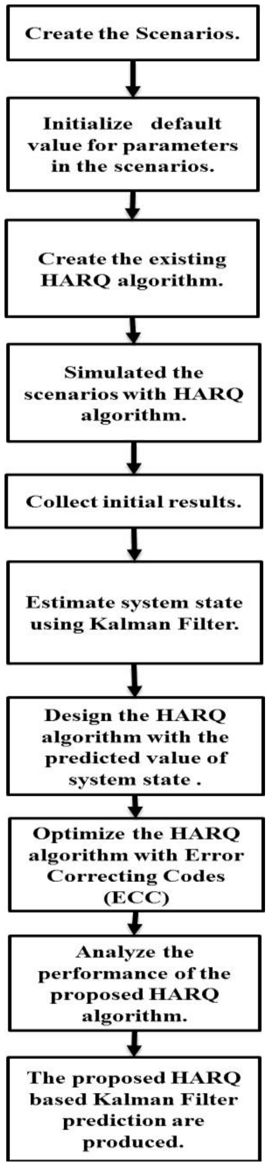


**Fig. 1:** The summarization of overall proposed methodology.

**Table 1:** Parameters used in analysis and simulation.

| Parameter | Value |
|---|---|
| Node Densities | 0.005, 0.01, 0.015, 0.02, 0.025, 0.03, 0.035 ($m^2$) |
| Distance between source and sink (L) | 100m |
| Min. distance between two nodes | 1m |
| Packet Sizes | 100, 200, 300, 400, 500 (Kbytes) |

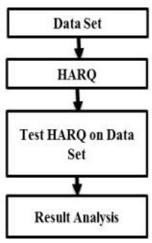


**Fig. 2:** Block Diagram of HARQ algorithm based on previous works.

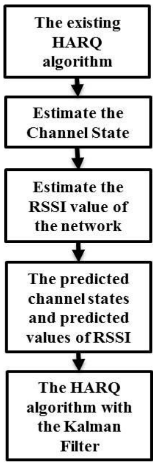


**Fig. 3:** Block Diagram on the estimation of channel states using Kalman Filter.

***3.4. Optimization of the proposed HARQ algorithm with Kalman Filtering with low overhead ECC:***

Step 3: The HARQ algorithm with the Kalman Filter predicted values will be optimized to be used along with proper type of ECC. The possible ECC listed in section 2.2 will be tested and the low overhead ECC with high error rates mitigation will be implemented accordingly to the channel states.

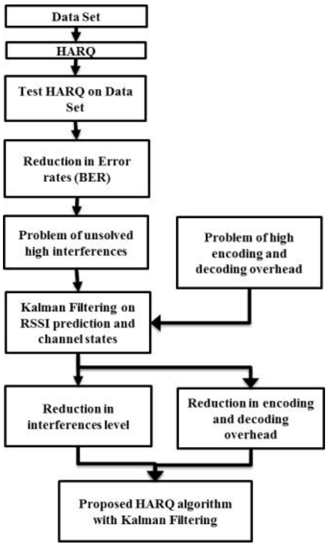


**Fig. 4:** Block Diagram on the optimization of proposed algorithm with Kalman Filtering and ECC.

Figure 4 above shows the block diagram of proposed HARQ algorithm with the Kalman Filter prediction. The problem of high interferences levels that cannot be solve with HARQ algorithm will be reduced with using the estimation of Kalman Filter and the problem of high encoding and decoding overhead due to complexity of ECC will be reduce by using proper ECC accordingly to channel state that will be predicted by Kalman Filtering and by the used of proper error correcting capabilities.

## 4. *Expected Results:*

From the latest previous work, we know that the algorithm of HARQ can boost the lifetime in terms of mitigating errors. However, the existing HARQ and from the previous work (Uma Datta & Kundu, 2014) has gap that needed to be solved. The HARQ algorithm cannot tolerate with high interference when being implemented in high densities of nodes and will degrade the lifetime as the node becomes condensed. The existing HARQ algorithm has been implementing ECC in FEC module and needed to be studied further the proper ECC to be implemented in such a high densities and inconsistent environment to reduce the overhead that could promote to the degradation in the lifetime of the network. Thus, by implementing the HARQ algorithm with the prediction by Kalman Filtering and proper ECC, the lifetime of the network are expected to be

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improvedalongside with the reduction of error rates, interference level and overhead in the network

***Conclusion:***

This paper had identified the possible previous works on the HARQ error protocol in the related work. The latest improvement on the HARQ and had showed some significant impact in improving the lifetime of WSN and error rates. We identified that the HARQ algorithm might work well in improving the lifetime of the network by mitigating errors. We also propose our algorithm of HARQ based on Kalman Filtering and ECC implementation. This paper expected that the HARQ based Kalman Filtering and proper ECC implantation might work to prevent additional overhead and lowering the interference levels to indirectly enhance the lifetime of WSN.

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