REVIEW ON CROSS LAYER HYBRID SCHEME IN WMSNS USING ERROR CORRECTING CODES FOR ENERGY EFFICIENCY

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ABSTRACT

Wireless Sensor Networks (WSNs) are energy constraint networks that require reliable data communication at a low cost of energy. Only one particular error correcting code (ECC) cannot be adopted for all applications and scenarios of WSNs. The use of a specific ECC depends on the requirements of the application and the constraints of the WSN. Hence it is very challenging to choose an optimum error correcting code for a WSN where both, the performance and energy consumption are taken into account. The selection of an optimum error correcting code for wireless sensor network has been widely studied by many researchers in the past but a standard is yet to be set. Therefore, we present a survey paper to provide reference of existing work on ECCs in WSN and help scholar's to find a standard ECC for WSNs. We survey different techniques used for error correction in WSNs for better performance and energy efficiency.

Keywords*: Wireless Sensor Network, Error Correcting Code, Energy efficiency.*

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1. INTRODUCTION

A Wireless Sensor Networks (WSNs) can be defined as a network of devices, denoted as nodes, capable of sensing the environment and communicating the information gathered from the monitored field through wireless links. The most important part of sensor node is the power unit which can be regarded as the soul of the sensor node because it supplies energy to node to carry out the assigned tasks. The power unit, in most cases, consists of batteries that have limited energy. Commonly, sensor nodes are deployed in remote unattended geographical areas where it is difficult or sometimes even impossible to replace batteries that supply energy to nodes. So the sensor nodes are generally operated by irreplaceable power sources. However WSN applications including industrial, security surveillance, medical, environmental and weather monitoring among others need the network to operate for a longer time period even in some cases the required life time of network is in years. Therefore the problem of how to extend life of WSN has been quite extensively studied in past few years.

All processes of a sensor node consume considerable amount of energy, however experimental measurements have shown that data transmission is very expensive in terms of energy consumption, while data processing consumes significantly less. For that reason it is very necessary to employ strategies that result in less energy consumption in data communication. For example, avoid unnecessary transmission by aggregating the data of correlated sensor nodes. Likewise the transceiver consumes higher energy in transmission and reception even in idle state, it consumes significant amount of energy, so the transceiver should be put to sleep (or turned off) whenever possible. All these solutions play an important role in extension of life of WSN but they are useless if reliability is not provided. For the reason that data transmitted from the source node to another node or to the base station (depending on the routing protocol being used) is prone to noise and interference which induces errors in it. Whereas the applications of wireless sensor network need reliable data communication as reliability is the fundamental requisite of every communication. Therefore to provide reliable data communication normally two techniques are used. First one is automatic repeat request (ARQ) and the other one is forward error correction (FEC). In ARQ the sender node adds error detection codes i.e. cyclic redundancy check or parity check codes to the data. Sink node checks the correctness of the received data if erroneous packet is received it is simply discarded and the sender node is requested to retransmit the same packet. This is the simple less complex technique which improves the throughput, requires less overhead and computation cost is cheap but the retransmitting strategy cannot improve the overall energy efficiency in WSN.

This makes a strong case in favour of second technique used for reliable data transmission which is forward error correction (FEC). In FEC source node encodes data using some error correcting code which lets the receiver node to correct errors in data packet if present, thus making retransmission outdated. Error control coding also provides coding gain which lowers required transmitting power for specific bit error rate (BER) or frame error rate (FER). However this happens at the cost of extra energy consumption in encoding, transmitting redundant bits and decoding. In most cases encoding energy is considered to be negligible while decoding process consumes significant amount of energy. Complex decoders provide better performance in term of BER but on the other hand consume more energy. WSNs are energy constraint and also require reliable data communication, so the data reliability must be provided at low energy cost. Hence it is very challenging to choose an optimum error correcting code for wireless sensor network where both, the performance and energy consumption are taken into account. Some researchers have studied hybrid automatic repeat request (HARQ) schemes which exploit advantages of both error correcting schemes by combining ARQ and FEC. HARQ is good for some scenarios in wireless sensor networks but it is limited to only specific applications and consumes a significant amount of energy.

The selection of an optimum error correcting code for wireless sensor network is widely studied by many researchers in the past decade but a standard is yet to be set. So to help the scholars in finding a standard optimum error correcting code (ECC) and to provide the reference of existing work on ECCs in WSN to the new researchers so that they can have knowledge of the recent research issues in this field. In this paper we survey different techniques used for error correction in WSN specifically we focus on ECCs.

2. RELATED WORKS

In recent years, many researchers have contributed their efforts towards power minimization in WSNs with respect to error correction codes. This section provides a brief review of related works.

In[1],Nabil Ali Alrajeh et al- have evaluated the performance of different ECCs which shows that stronger codes provides good performance but are energy inefficient in contrast performance of simple codes is poor but are most energy efficient. Implementation strategy of error control plays an important role in selection of a specific ECC. Stronger codes are optimal to be used with end to end error control strategy while simple codes are best for node to node error control strategy. Furthermore they studied the implementation strategies of error control techniques in WSNs and analyze some energy models to find the energy efficiency of different ECCs.

In [2], Halil Yetgin et al- have evaluated the network lifetime of WSNs by analysing the impact of physical layer parameters as well as the signal processing power on network lifetime. But they concluded that the network lifetime reduce as the BER reduces because of accumulated Energy dissipation of Signal processing power and transmit power. They have presented experimental results for assisting the network designer in making informed decisions as to which modulation and coding schemes work well for the application supported.

In [3], M. Yousof Naderia et al-have presented a comprehensive performance evaluation for different error control scenarios in WMSNs by conducting extensive simulations. It was shown that the existing error control protocols cannot provide a single overall best scheme for real-time multimedia delivery in WSNs. They shown that cross layer hybrid schemes improve the quality of perceived video at the sink node compared to simple schemes at low bit error rates but it is energy inefficient. The RS scheme is video efficient but it could not provide acceptable video quality. They concluded that cross layer hybrid schemes seem to be promising for addressing multimedia challenges if their energy efficiency is improved and they could be suitable candidates for delay sensitive traffic in WSNs.

In [4], Ghaida A. AL suhail et al- put forward a scheme for wireless sensor network that the source node has the ability to adapt the error correction capability for each transmission. The maximal energy efficiency of HARQ technique can be achieved by adaptation of error correction capability for a target communication distance and packet size. Moreover, AECC (Adaptive Error Correction Code) is compared with non-AECC scheme in terms of energy efficiency based on different communication distances and packet lengths.

In [5], M. Vuran and I. Akyildiz - have proposed a cross-layer analysis of error control schemes for WSNs. They consider the impacts of routing, medium access, and physical layers in sensor networks. Forward error correction (FEC) coding improves the error resiliency by sending redundant bits through the wireless channel. It is shown that this improvement can be exploited by transmit power control or hop length extension through channel-aware cross-layer geographical routing protocols in WSNs. It has been shown that the selection of suitable error control scheme depends on the physical architecture of the sensor nodes as well as the end-to-end distance and target PER. Furthermore, the advantages of FEC schemes in high density networks with high traffic rate are also highlighted. Finally, FEC and hybrid ARQ schemes are shown to significantly improve the end-to-end latency performance of WSNs through hop length extension without hampering the energy efficiency and the end-to-end PER. This makes these schemes important candidates for delay sensitive traffic in WSNs when used in combination with retransmissions in hybrid ARQ schemes.

In[6], Z. Tian et al-have compared an ARQ with FEC schemes in terms of energy efficiency and the cases where ARQ outperforms FEC and where FEC is more energy efficient are analyzed. Energy efficiency of ARQ technique is independent of retransmission attempts and is unchangeable with the number of retransmission. And there is an optimum FEC scheme with the maximal energy efficiency for a target communication distance and packet size. Moreover, ARQ is compared with FEC in terms of energy efficiency based on different communication distances and packet lengths.

In [7], Heikki Karvonen, focused on a cross-layer analysis of several aspects of communication and networking in WSNs and WBANs. An introduction to wireless sensor networks was provided, and relevant existing works on RF communication energy efficiency improvement were reviewed. A generic wake-up radio-based MAC protocol was proposed to enable energy efficiency by avoiding idle listening, and it was incorporated to the developed models. He proposed a model which takes PHY and MAC layer characteristics jointly into account in a star-topology network transmission period length and energy efficiency analysis for the group of sensor nodes transmitting to the sink node. The authors proposed model enables to perform cross-layer design using the information exploitation approach, which takes advantage of information exchange between the different layers in order to improve their joint energy efficiency.

In [8], Jong-Suk Ahn et al- Authors extend the 802.11 evaluation model to analyze throughput and energy demand of 802.11 with RS codes over WSNs. The application of the evaluation model to the abstracted WSNs shows that 802.11 with RS codes outperforms the original 802.11 in terms of two performance metrics. It also indicates that the RS symbol size can significantly vary throughput and energy saving over short-term durations while the long-term average of these two metrics seldom depends on the symbol size.

In [9], Hao Wen et al- have presented a simple and realistic analytical model to analyze the packet arrival probability and average energy consumption of retransmission and Erasure Coding. They have quantitatively evaluated the comprehensive impact on reliability and energy efficiency of the two approaches, where Erasure Coding indicates flexibility against packet loss, from a ulp(unconditional loss probability) of 0.5 in one hop to a ulp of 0.07 in a multihop fashion. Notable was its energy efficiency while achieving reliability under low or moderate loss conditions, even compared with efficient retransmission. However, their analytic results indicate that, performance advantage weakens with an increase in hop number. Moreover, it was necessary to consider the trade off between reliability and energy efficiency for Erasure Coding.

In [10], B. Manzoor et al- The authors have studied and compared energy efficiency of three different error correction and detection strategies when implemented with cooperative diversity. They investigated the use of ARQ, HARQ and FEC for error correction and detection in WSNs. They also investigated significance of SRC (Single Relay Cooperation) and MRC (Multi Relay Cooperation) when applied along with these schemes. The results reveal that ARQ, HARQ and FEC along with SRC and MRC have significantly enhanced system performance. The authors have evaluated the performance on the basis of Throughput, Delay, BER (Bit Error Rate) and SER (Symbol Error Rate).

In [11], Jyothi B R and Sangamesh G Tamburimath- have implemented the EG-LDPC (Euclidean geometry low density parity check) decoder with less complexity and increased decoding speed and the errors also successfully detected if exists. The simulation outcomes shown that all tested combinations of errors affecting around four bits are detected in the first three iterations of decoding. The simulation results presented that all errors affecting three and four bits would be detected in the first three iterations. For errors affecting a larger number of bits, there is a small probability of not being detected in those iterations. For large word sizes, the probabilities are sufficiently small to be acceptable in many applications.

In [12], Yong Jin et al-proposed a link-level hybrid FEC/ARQ mechanism for supporting the wireless multimedia application. They analyzed the performance of the hybrid model based on an adaptive FEC. They applied the hybrid FEC/ARQ mechanism at the data link layer to decrease the round trip time and the packet loss rate. They investigated in both analytic and simulation approaches and demonstrated that the hybrid FEC/ARQ mechanism provides a significant improvement in the reliability and the real-time performance of wireless media streaming transmission, with adapting to the fluctuation of the wireless network state dynamically.

3. ERROR CORRECTION CODES IN WSNs

Error correcting codes insert parity bits into message sequence in a proper way depending on type of code being used. The parity bits allow the receiver to correct errors in message sequence introduced due to noise or interference during transmission. There are basically two types of error correction codes: (1) Block codes and (2) Convolutional codes.

3.1 ARQ

Automatic Repeat Request (ARQ) is an error control method that uses the retransmission mechanism when data packets have been lost. Although some ARQ protocols enable the receiver to request retransmission of lost packets if an error is detected, if timeout occurs before the transmitter receives acknowledgment from the receiver, the packet is retransmitted until it is correctly received or the predetermined maximum number of retransmissions (N) is reached. Moreover, when errors occur, the ARQ protocol introduces additional variable delay, overhead, and energy consumption costs, while it may outperform other schemes when channel conditions are suitable. Therefore, the efficiency of ARQ in WMSNs varies based on channel conditions, as well as the delay and energy constraints of the environment.

3.2 Link-layer FEC

In wireless link-layer FEC, the sender node adds some redundancy to the source packets and transmits them toward the sink node. The redundant information is used by the receiver to detect and correct errors. Depending on the amount and structure of the redundancy, the receiver node can receive error-free packets even if some transmission bit errors occur. The two most widely used schemes in FEC are block codes (BCH and RS codes) and convolutional codes. Block codes are processed on a block-by-block basis and convolutional codes are processed on a bit-by-bit basis.

3.3 Erasure coding (EC)

Erasure coding is an error control scheme for application-level FEC that is used to handle losses in real-time communication. In the coding theory, an error is defined as a corrupted symbol in an unknown position, while an erasure is a corrupted symbol in a known position. Fig. 1 shows how erasure coding is applied to groups of media packets that are transmitted to the sink sensor node. Indeed, an (k,n) block RS erasure code encodes n input media packets into a group of k coded packets by generating k-n additional packets and is denoted by EC(k,n). At the sink node, we can reconstruct n original media packets by receiving any n out of k packets (k > n). Clearly, the packet-level RS erasure coding is a completed different mechanism than link-layer RS coding, and it has been employed in WSNs and wireless multimedia networks due to its suitability for video communications and the nature of error coding at the application layer.

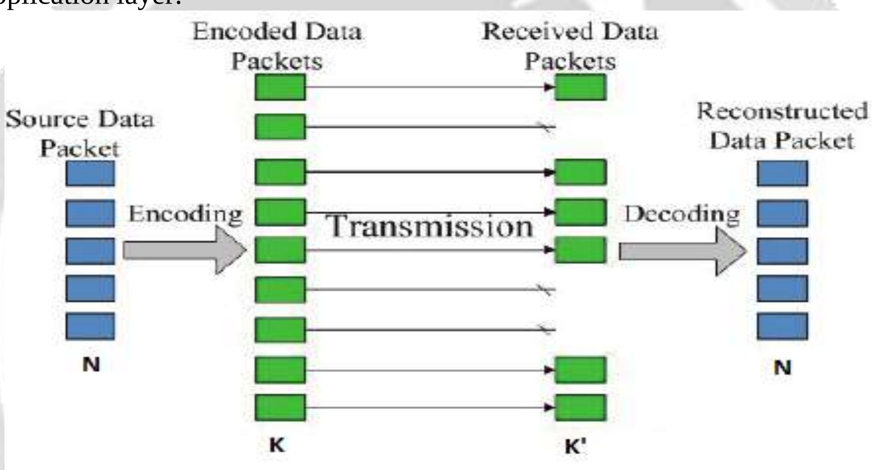

Fig-1: Mechanism of erasure coding

3. 4 Low density parity check codes (LDPC)

An LDPC code is defined as the null space of a parity check matrix H with the following structural properties: (1) each row consists of ρ “ones”; (2) each column consists of γ “ones”; (3) the number of “ones” in common between any two columns, denoted λ, is no greater than 1; (4) both ρ and γ are small compared to the length of the code and the number of rows in H. Since ρ and γ are small, H has a small density of “ones” and hence is a sparse matrix. For this reason, the code specified by H is called an LDPC code. The LDPC code defined above is known as a regular LDPC code. If not all the columns or all the rows of the parity check matrix H have the same number of “ones” (or weights), an LDPC code is said to be irregular.

3. 5 Cross-layer hybrid schemes

There is an increase in number of research activities in wireless multimedia and wireless sensor networks that have focused on the cross-layer design and integration of protocols as an important paradigm to increase the efficiency of the overall system, enhance the video quality and maximize the usage of network resources. Generally, there are two possible cross-layer design approaches: integrating functionalities of different layers in a single protocol and establishing tight cooperation between adjacent or non- adjacent layers [3]. The former cross-layer design approach results in reduction of the overhead and also provides the capability to implement advanced QoS mechanisms. The latter cross-layer case results in better reactivity to network fluctuations and other external factors by inter-layer interactions and cross-layer optimization [3].

4. PREVIOUS RESULTS AND DISCUSSIONS

Several authors presented their views on error correcting codes in WSN for energy efficiency.
The simulation results [3] are shown in Table.1

Table-1: Simulation results of [3]

Performance metric	The most efficient scheme	The worst scheme
Frame loss rate	Cross Layer(4,106,4)	Erasure coding
PSNR	Cross Layer(4,106,4)	ARQ, Erasure coding
Energy Efficiency	**RS**	**Cross Layer(4,106,4)**
Cumulative Jitter	Cross layer	ARQ, RS, Erasure coding

According to the results, cross-layer hybrid schemes seem to be promising for addressing multimedia challenges, and if their energy efficiency can be improved, they could be suitable candidates for delay-sensitive traffic in WSNs.

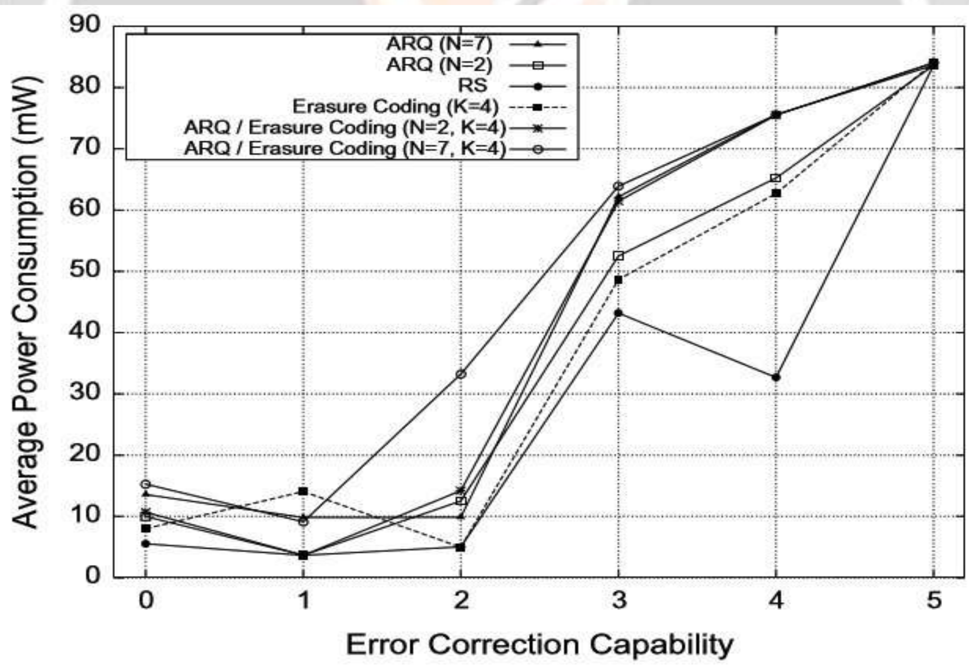

Fig-2: Average power consumption vs. error correction capability

Fig.2. shows that, as the error correction capability increases, the energy consumption of cross-layer hybrid scheme increases. It can be observed that the simple RS scheme consumes less power than the other schemes. Moreover, the cross-layer hybrid ARQ/Erasure coding scheme consumes more energy than the other schemes, regardless of error correction capability. This means that, although cross-layer schemes can provide acceptable video quality for delay- sensitive multimedia communications in

sensor networks, they are not energy efficient. Furthermore, ARQ (N = 7) is less energy efficient than ARQ (N = 2) and Erasure coding (k = 4) schemes [3].

5. CONCLUSION

In this paper a review on error correcting codes for energy efficiency is presented. Although in several cases the cross-layer hybrid scheme provided the best performance, it was inefficient in terms of energy consumption compared to the other error control schemes. In particular, it resulted in better perceived video quality at the cost of increasing energy. The RS scheme energy consumption was more efficient than other schemes, but it could not provide acceptable video quality at the receiver when the error rates were high [3]. Further more if LDPC code is used alone then power consumption is more. If we use LDPC in cross layer hybrid scheme, we may achieve less power consumption and better video quality [1].

6. REFERENCES

[1] Nabil Ali Alrajeh, Umair Marwat, Bilal Shams and Syed Saddam Hussain Shah, Error Correcting Codes in Wireless Sensor Networks: An Energy Perspective, International Journal of Appl. Math. Inf. Sci. 9, No. 2, 809-818 (2015).

[2] Halil Yetgin, Kent Tsz Kan cheung, Mohammed El-Hajjar and Lajos Hanzo, Cross layer network lifetime optimisation considering transmit and signal processing power in wireless sensor networks, IET Wirel. Sens. Syst., 2014, Vol. 4, Iss. 4, pp. 176–182 .

[3] M. Yousof Naderia, Hamid R. Rabiee a, Mohammad Khansari b, Mostafa Salehi, Error control for multimedia communications in wireless sensor networks: A comparative performance analysis, Journal of Ad Hoc Networks 10, Elsevier (2012) 1028–1042

[4] Ghaida A. AL-Suhail, Khalid W. Louis, and Turki Y. Abdallah. Energy efficiency analysis of adaptive error correction in wireless sensor networks. International Journal of Computer Science Issues, 9(4):1–79, July 2012.

[5] M. Vuran, I. Akyildiz, Error control in wireless sensor networks: a cross layer analysis, IEEE/ACM Transactions on Networking 17 (4) (2009) 1186–1199.

[6] Zhen Tian, Dongfeng Yua and Quanquan Liang, Energy Efficiency Analysis of Error Control Schemes in Wireless Sensor Networks,IEEE, 2008, 978-1-4244-2202-9/08.

[7] Heikki Karvonen, Energy Efficiency Improvements For Wireless Sensor Networks By Using Cross-Layer Analysis, Acta Univ. Oul. C 520, 2015.

[8] Jong-Suk, Y. Jong-Hyuk, L. Kang-Woo, Performance and energy consumption analysis of 802.11 with FEC codes over wireless sensor networks, Journal of Communication and Networks 9 (3) (2007) 265–273.

[9] H. Wen, C. Lin, F. Ren, Y. Yue, X. Huang, Retransmission or redundancy: transmission reliability in wireless sensor networks, IEEE International Conference on Mobile Adhoc and Sensor Systems (2007) 1–7.

[10] B. Manzoor, N. Javaid, O.Rehman, S. H. Bouk, S. H. Ahmed and D. Kim, Energy Aware Error Control in Cooperative Communication in Wireless Sensor Networks, ACM Research in Adaptive and Convergent Systems (RACS 2013), Montreal, Canada.

[11] Jyothi B R and Sangamesh G Tamburimath, Energy Efficient Layer Decoding Architecture for LDPC Decoder, IJCRD,2321-2241 Volume: 4; Issue: 1; January -2015.

[12] Y. Jin, G. Bai, P. Zhang, H. Shen, J. Wang, Performance evaluation of a hybrid FEC/ARQ for wireless media streaming in: 4th IEEE International Conference on Circuits and Systems for Communications, 2008, pp. 90–94.

[13] B. Liu, F. Ren, C. Lin, Y. Ouyang, Performance analysis of retransmission and redundancy schemes in sensor networks, in: IEEE International Conference on Communications, 2008, pp. 4407– 4413.

[14] J.S. Ahn, Y.S. Lee, J.H. Yoon, K.W. Lee, Analyzing the effect of a block FEC algorithms symbol size on energy consumption in wireless sensor networks, in: H. Youn, M. Kim, H. Morikawa (Eds.), Ubiquitous Computing Systems, Lecture Notes in Computer Science, vol. 4239, Springer, Berlin/Heidelberg, 2006, pp. 440–453.

[15] C.F. Chiasserini, E. Magli, Energy-efficient coding and error control for wireless video-surveillance networks, Telecommunication Systems 26 (2004) 369–387.

[16] Sartipi, Mina and FaramarzFekri. Source and channel coding in wireless sensor networks using ldpc codes, 2004.

[17] G. Balakrishnan, M. Yang Y. Jiang, and Y. Kim. Performance analysis of error control codes for wireless sensor networks. Int. Conf. Information Technology (ITNG07), pages 876–879, April 2 2007

[18] Priyanka Shrivastava,Uday Pratap Singh, Error Detection and Correction Using Reed Solomon Codes, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 8, August 2013.

[19] M.P.Singh, Prabhat Kumar, an Efficient Forward Error Correction Scheme for Wireless Sensor Network, Elsevier Procedia Technology 4 (2012) 737 – 742

[20] Rubal Chaudhary, Vrinda Gupta, Error Control Techniques and Their Applications, International Journal of Computer Applications in Engineering Sciences (VOL I, ISSUE II, JUNE 2011).

[21] Oskar Eriksson. Error control in wireless sensor networks a process control perspective. http://www.teknat.uu.se/student, November 2 2011.

[22] Mohammad Rakibul Islam, Error Correction Codes in Wireless Sensor Network: An Energy Aware approach, World Academy of Science, Engineering and Technology 37 2010.