Lifetime Enhancement of Wireless Sensor Networks using Duty Cycle, Network Coding and Cluster Head Selection Algorithm

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Abstract - ***The lifetime of wireless sensor network is a critical factor that needs to be addressed by considering different parameters that affect the lifetime of wireless sensor network. The lifetime of WSN mostly depends on energy consumption by node.***

The enhancement of network lifetime is carried out by considering different parameters including duty cycle management, network coding, cluster head selection, routing and selection of topology. Each method has its advantages and disadvantages. In the duty cycle management approach the energy efficiency of network increases but there is no provision for packet latency. In network coding approach packet latency is considered but efficient routing algorithm is not introduced. This leads us to couple the advantages of various methods for lifetime optimization and provide an efficient solution for lifetime optimization.

Key Words: *Duty cycle, cluster head, lifetime etc…*

1. INTRODUCTION

Wireless sensor network (WSN) has great advantages in day to day life i.e. it is widely used in the commercial and industrial areas such as environmental monitoring, healthcare, process monitoring and surveillance. WSN is a network which is consist of small devices known as nodes. Nodes are consisting of CPU, memory, battery and transceiver [10].The operation of WSN depends on the parameters like network lifetime, topology of the network, weather conditions, type of the node and zone around the sink node. In our work we are concentrating on the WSN lifetime. The lifetime of the WSN depends on the battery life, energy consumption by nodes and packet loss. These parameters can be controlled by different approaches like duty cycle management, Network coding, topology management, routing algorithms. In our work we have implemented the duty cycle management approach and introduced other approaches including network coding and cluster head selection.

The limited battery lifetime of nodes also affects the overall lifetime of WSN. Heavy traffic on the sensor nodes near sink also has effect on network lifetime [1]. If we switch the node in sleep and active mode then it leads to energy saving of the node. The concept of switching the node in active and sleep mode can be achieved with the help of duty cycle. Duty cycle is nothing but the ratio of active time of the node to its total time. With the help of the duty cycle the nodes can be activated whenever it wants to transmit the data to the sink otherwise it will be in sleep mode and if the node is in sleep mode then the energy consumption is automatically reduced.

At the time of transferring the data there may be the loss of packets i.e. the original packet may not be received at sink. This ambiguity can be solved by the network coding technique. Network coding is the technique which allows the intermediate node to encode the data and transfer it to the next node and at the receiver node original data will be decoded. That approach of network coding gives us the reliability of transferring original data at better packet delivery ratio. If the unwanted data packets are neglected then obviously the energy consumption also reduces and it leads to lifetime enhancement of WSN.

The data transferred using routing algorithm is the efficient way of transmission. There are number of routing algorithms available, but the cluster head selection algorithm is more efficient. In cluster head selection method one of the nodes from a cluster is selected as the cluster head and that is used to gather the data from the neighboring node and transfer it to the base station or sink node [4]. The cluster head selected on the basis of residual energy and lowest mobility factor. This approach provides better routing algorithm. Better routing for communication then leads to lifetime optimization. In our implemented work we have used cluster head selection algorithm, duty cycle management and the network coding approach together for better results.

2. LITERATURE REVIEW

This section briefly outlines the related works carried out by researchers in the area of lifetime enhancement of WSN.

Duty cycle is used to reduce the energy consumption in the WSN. Rashmi Ranjan Rout et al. [1] have derived the combination of duty cycle and network coding for lifetime enhancement. In this work they achieved the good energy efficiency and good packet delivery ratio. But it does not elaborate on the routing algorithms. Also the multi-hop communication is not considered.

Low – power- listening MAC protocol, AADCC and DDCC approaches used for duty cycle controlling by Christophe J. Merlin et al. [2].lead to less energy consumption but AADCC gives better result than the DDCC. Here the low energy consumption is achieved but has the disadvantage of packet loss and due to the packet loss the data communication gets affected.

HeejungByun el al. [3] proposed Adaptive Duty Cycle Control with Queue Management in WSN. Here the queue management of the duty cycle is only considered, so this work only concentrates on duty cycle. The energy efficient WSN is achieved but due to the queue management the end to end delay is increased and has the disadvantages of packet delivery ratio due to packet loss.

Qinghua Wang, and Tingting Zhang [4] proposed Bottleneck zone analysis in Energy-constrained wireless sensor network. This work concentrates on the bottleneck zone which is around the sink node. They work out for lowering the traffic in this zone. Therefore as the traffic is minimised the collisions between the data packets are minimized and the energy consumption gets reduced.

The network coding was introduced by Ahlswede et al. [5] in the field of information network. They introduced this method for the better and efficient communication. The network coding has two phases i.e. encoding and decoding. The encoding is done at intermediate node and decoding is done at the receiver node. Because of the encoding and decoding approach, the transmission of original data to the sink is efficiently done. Here the packet delivery ratio is achieved but energy efficiency is not achieved.

Lun et al. [6] proposed The network coding based approach that improves the packet level capacity of the network. This work implements only network coding approach for efficient packet delivery. In this work they introduced the packet capacity, but do not have any routing scheme for better transmission. Therefore the energy consumed by the network may increase for transmitting the data along the unknown way. The network coding based routing scheme is presented by Rout et al [7]. In this work the routing algorithm is derived for the efficient transfer of the data packet. Therefore the unwanted energy consumption is reduced by introducing the routing algorithm. But in both the above work there is no provision for energy conservation of the node.

The cluster head selection is also available for the energy efficient WSN. The work done by Do-Seong Kim and Yeong- Jee Chung propose LEACH-Mobile [9] (LEACH-M) concentrates on routing protocol which is applicable to Wireless mobile networks. But in this protocol, transmission overhead is increased to send a message because of membership declaration. To move forward this problem, Santhosh Kumar G et al. propose LEACH-Mobile-Enhanced [10] (LEACH-ME), the node with a lowest mobility factor is selected as a CH. But LEACH-ME consumes more energy for determining mobility factor of the each node and this affects the lifetime of the WSN.

There is also work done by R.U. Anitha et al. [11] for energy efficient cluster head selection algorithm in mobile WSN. Here they introduced the energy efficient method for the selection of cluster head, so they achieved the energy efficiency but the packet delivery ratio is not achieved.

As the cluster head provides the better routing algorithm but does not provide better energy efficient algorithm because all nodes are active throughout the operation, therefore the nodes losses the energy at that time.

3. METHODOLOGY

In our work we have used three methods i.e. duty cycle, network coding and cluster head selection together.

3.1 Duty Cycle – It is implemented to switch the node in sleep and active mode. In our work for the simple design and no additional overhead, we have considered the random Duty cycle.

3.2 Network coding – In our work we are encoding the data at intermediate node in following manner.

At intermediate node first we convert the incoming data into the ASCII code after that we convert that ascii code into the string. After that conversion reverse that string. This process is done for encoding the data. Then at receiver, reverse process of encoding is done for the decoding.

3.4 Cluster head selection – In this, first we form the five overlapping clusters. After the cluster formation we search for maximum flow, residual energy of the node in the cluster. On the basis of maximum flow and maximum energy that node is selected as cluster head.

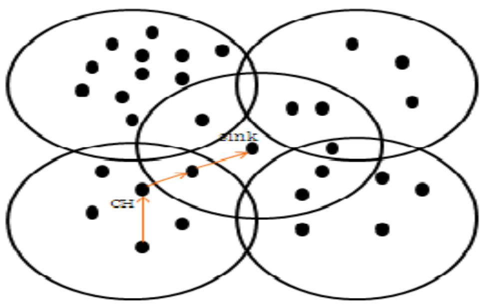

Fig.1. Data transmission from CH to the base station

The next phase is for the communication i.e. for transferring the data packet from CH to the base station as shown in fig.1, for this purpose the better routing algorithm will be assigned. The data is now ready to transfer to the sink. Since we are using the network coding approach, before transferring the data towards the sink it has to be encoded by the intermediate node. After receiving the data at receiver the original packet has to be decoded.

The same process mentioned in different phases above will be carried out in the next cycle of data transfer. The cluster formation, routing and data transmission is shown in fig. 1.

4. SIMULATION PARAMETERS:

Some of the important parameters which we are implemented in our proposed work are as follows.

Frequency – 5.9 GHz

Band Width – 10 MHz

Packet size – 960 bits

Packet send rate – 40 Kbps

For the better comparison, first we simulate the duty cycle and network coding techniques on NS2. After that we introduce cluster head selection method in it and again simulate on NS2.

Table – 1: Parameter setting

5. SIMULATION RESULTS:

5.1 LIFETIME

Table 2 – Lifetime Comparison table between [1] and our work using Duty cycle and Network coding

Duty cycle	Lifetime(sec) [1]	Lifetime (sec)	% error
0.01	5.2	5.54	6.13
0.02	2.9	3.1	6.45
0.03	1.7	1.66	-2.4
0.04	1.1	1.216	9.53
0.05	0.8	0.9025	11.35
0.06	0.6	0.6166	2.69
0.07	0.5	0.6	16.66
0.08	0.4	0.38	-5.26
0.09	0.3	0.312	3.846

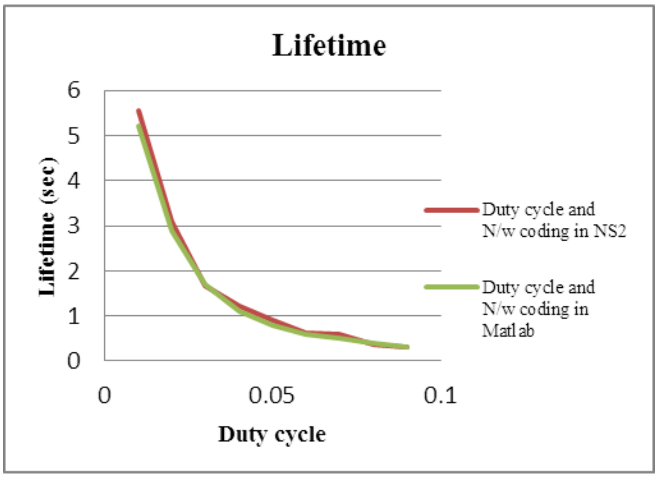

Fig-2: Network lifetime vs Duty cycle using Duty cycle and N/w coding technique

From the above graph it is observed that Network lifetime of [1] and our work by using duty cycle and network coding is found nearly equal.

Table 3 – Lifetime Comparison table between [1] and our work using Duty cycle, N/w coding and CH selection

Sr. No.	Parameters	Values
1.	Number of nodes	1000
2.	Area	200 x 200m^2
3.	Bottle neck zone radius	60 meters
4.	α11	0.937 µjoule per bit
5.	α12	0.787 µjoule per bit
6.	α2	0.0172 µjoule per bit
7.	Path loss exponent	2
8.	Eb	25Kjoule

Duty cycle	Lifetime [1]	Lifetime(sec) by D.C and n/w coding	Lifetime (sec)by D.C,n/w coding and CH	% rise w.r.t. [1]	% rise w.r.t D.C,n/w coding and CH
0.01	5.2	5.54	7.3	28.76	24.1
0.02	2.9	3.1	5.42	46.49	42.8
0.03	1.7	1.66	4.78	64.43	65.3
0.04	1.1	1.216	4.125	73.33	70.5
0.05	0.8	0.9025	3.87	79.32	76.67
0.06	0.6	0.6166	3.24	81.48	80.96
0.07	0.5	0.6	3.12	83.97	80.76
0.08	0.4	0.38	2.956	86.46	87.14
0.09	0.3	0.312	2.457	87.78	87.3

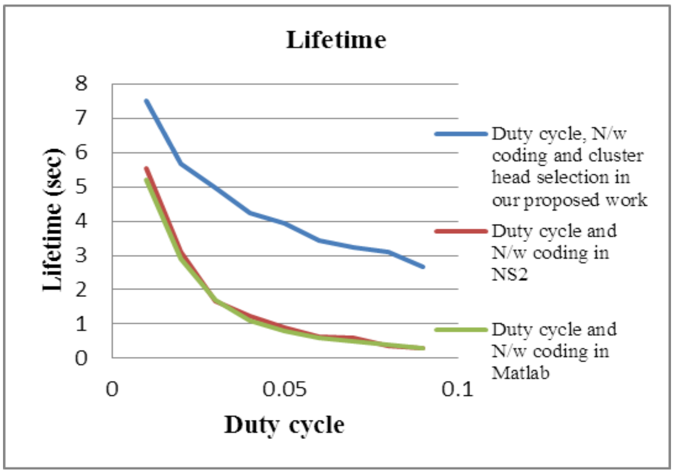

Fig.3- Network lifetime vs Duty cycle

From the above graph it is observed that network lifetime by using Duty cycle, network coding and cluster head selection is improved than the network lifetime using duty cycle and network coding.

5.2 ENERGY CONSUMPTION

Table 4 – Energy Comparison table between [1] and our work using Duty cycle and Network coding.

Duty cycle	Energy (uj) [1]	Energy by D.c,n/w coding (uj)	% error
0.01	50	46	-8.69
0.02	90	84	-7.14
0.03	160	156	-2.56
0.04	230	226	-1.73
0.05	310	307	-0.96
0.06	400	396	-1.01
0.07	520	515	-0.97
0.08	680	672	-1.19
0.09	790	784	-0.765

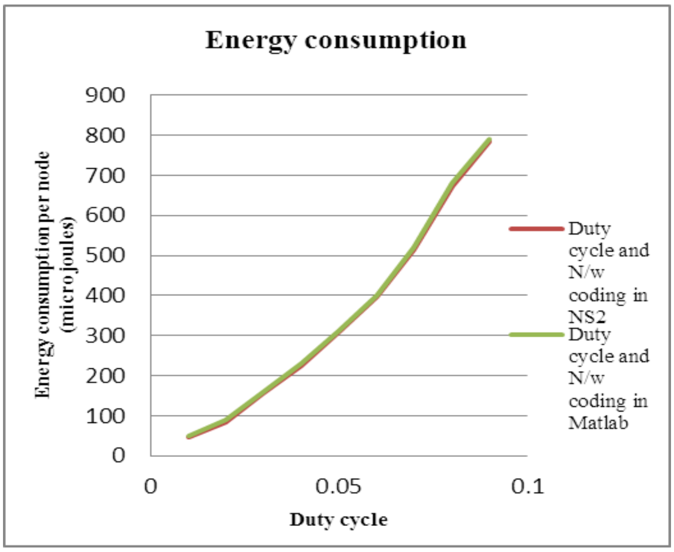

Fig.4- Per node energy consumption vs Duty cycle using only D.C &Nw coding

From the above graph it is observed that energy consumption per node of [1] and our work by using duty cycle and network coding is found nearly equal.

Table 5 – Energy Comparison table between [1] by using D.C. and network coding and our work using D.C, N/w coding and CH selection

Duty cycle	Energy (uj) [1]	Energy by D.c,n/w coding (uj)	Energy by D.c,n/w coding and CH (uj)	% error w.r.t. [1]	% error w.r.t D.C,n/w coding and CH
0.01	50	46	38	-31.57	-21.1
0.02	90	84	77	-16.88	-9.09
0.03	160	156	119	-34.45	-31.1
0.04	230	226	202	-13.86	-11.9
0.05	310	307	283	-9.54	-8.5
0.06	400	396	365	-9.58	-8.49
0.07	520	515	415	-25.30	-24.1
0.08	680	672	575	-18.26	-16.9
0.09	790	784	628	-25.79	-24.8

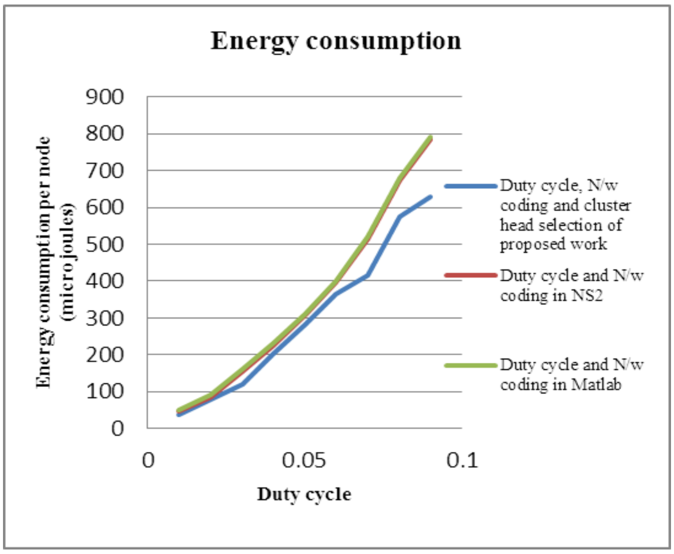

Fig.5- Per node energy consumption vs Duty cycle

From the above graph it is observed that energy consumption per node by using Duty cycle, network coding and cluster head selection is reduced than the energy consumption per node using duty cycle and network coding.

5.3 PACKET DELIVERY RATIO

Table 6– PDR Comparison table between [1] and our work using Duty cycle and Network coding.

Node Density (N/m^2)	PDR [1]	PDR by D.C. and n/w coding	% Error
0.015	0.22	0.2379	7.52
0.02	0.57	0.56	-1.78
0.025	0.76	0.72	-5.55
0.0275	0.81	0.83	2.40
0.033	0.96	0.98	2.04
0.04	0.96	0.98	2.04

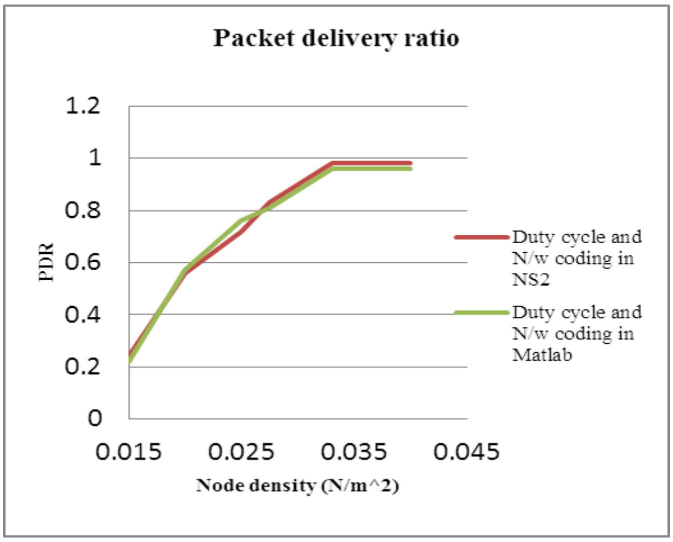

Fig.6- Packet Delivery ratio vs node density.

From the above graph it is observed that Packet delivery ratio of [1] and our work by using duty cycle and network coding is found nearly equal.

Table 7– PDR Comparison table between [1] by using D.C. and network coding and our work using D.C, N/w coding and CH selection

Node Density (N/m^2)	PDR [1]	PDR by D.c. & n/w coding	PDR by D.c,n/w coding and CH	% rise w.r.t. [1]	% rise w.r.t D.C,n/w coding and CH
0.015	0.22	0.2379	0.25	12	4.84
0.02	0.57	0.56	0.58	1.72	3.45
0.025	0.76	0.72	0.77	1.29	6.49
0.0275	0.81	0.83	0.84	3.57	1.19
0.033	0.96	0.98	1	4	2
0.04	0.96	0.98	1	4	2

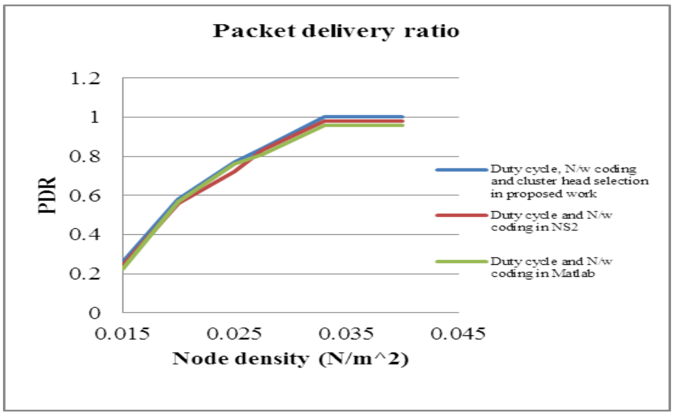

Fig.7- Packet Delivery ratio vs node density

From the above graph it is observed that Packet delivery ratio by using Duty cycle, network coding and cluster head selection is improved than the Packet delivery ratio using duty cycle and network coding.

5.4 THROUGHPUT

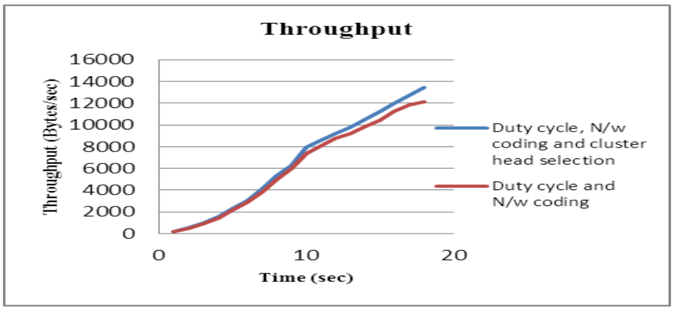

Fig.8- Throughput vs Time

From the above graph it is observed that throughput using duty cycle, network coding and cluster head selection is improved than the throughput by using duty cycle and network coding.

6. CONCLUSIONS

The operation of WSN depends on the network lifetime. Here we carry out the results by implementing duty cycle, network coding and cluster head selection technique together. It has been observed that there is the reduction in energy consumption in WSN. This leads to increase in network lifetime. Simulation results reveal that there is an average increase of 70.22% in network lifetime for 1% to 9% duty cycle than the lifetime using duty cycle and network coding [1]. It has been shown that energy consumption per node is also reduced. The energy consumption per node is reduced by 20.58% than energy consumption per node using duty cycle and network coding [1]. The packet delivery ratio of our work is improved by 4.43% than the Packet delivery ratio using duty cycle and network coding [1]. We also achieved the throughput of the WSN by implementing duty cycle, network coding and cluster head selection technique together.

REFERENCES

[1] RashmiRanjan Routand Soumya K. Ghosh," Enhancement of Lifetime using Duty Cycle and Network Coding in Wireless Sensor Networks" *IEEE Transactions On Wireless Communications,* Vol. 12, No. 2, February 2013.

[2] Christophe J. Merlin and Wendi B. Heinzelman," Duty Cycle Control for Low-Power-Listening MAC Protocols" *IEEE Transactions On Mobile Computing,* Vol. 9, No. 11, November 2010.

[3] HeejungByun and Junglok Yu," Adaptive Duty Cycle Control with Queue Management in Wireless Sensor Networks" *IEEE Transactions On Mobile Computing,* Vol. 12, No. 6, June 2013.

[4] Qinghua Wang,and TingtingZhang,"Bottleneck zone analysis in Energy-constrained wireless sensor network ", *Ieee Communications Letters,* Vol. 13, No. 6, June 2009.

[5] R. Ahlswede, N. Cai, S. Y. R. Li, and R. Yeung, "Network information flow," *IEEE Trans. Inf. Theory*, vol. 46, no. 4, pp. 1204–1216, July 2000.

[6] D. Lun, M. Medard, R. Koetter, and M. Effros, "On coding for reliable communication over packet networks," *Physical Commun.*, vol. 1, pp. 3–20, 2008.

[7] R. R. Rout, S. K. Ghosh, and S. Chakrabarti, "A network coding based probabilistic routing scheme for wireless sensor network," in *Proc. 2010Int. Conf. on Wireless Communication and Sensor Networks*, pp. 27–32.

[8] Osameh M. Al-Kofahi and Ahmed E. Kamal," Network Coding-Based Protection of Many-to-OneWireless Flows" *Ieee Journal On Selected Areas In Communications,* Vol. 27, No. 5, June 2009.

[9] Do-Seong Kim and Yeong-Jee Chung, "Self-Organization Routing Protocol Supporting Mobile Nodes for Wireless Sensor Network", Proceedings of the *First International Multi-Symposiums on Computer and Computational Sciences (IMSCCS'06),* 2006.

[10] G. S. Kumar, M. V. Vinu Paul, G. Athithan and K. P. Jacob, "Routing Protocol enhancement for handling node mobility in wireless sensor networks," In *TENCON 2008 - 2008 IEEE Region 10 Conf*, 2008, pp. 1- 6.

[11] R.U.Anitha and Dr.P.Kamalakkannan," *Energy Efficient Cluster Head Selection Algorithm in Mobile Wireless Sensor Networks*", 2013 International Conference on Computer Communication.

[12] C.KarthikSendhil Kumar, R.Sukumar, M.Nageswari, "Sensors Lifetime Enhancement Techniques in Wireless Sensor Networks - A Critical Review", *IRACST - International Journal of Computer Science and Information Technology & Security (IJCSITS), ISSN: 2249-9555* Vol. 3, No.2, April 2013.