ELEKTROPIKA: Int. J. of Electrical, Electronic Engineering and Technology, Vol. 4, pp. 39-46, 2017

IMPLEMENTATION OF WIRELESS SENSOR NETWORK WITH TWO BASE STATIONS

Ekhlas K. Hamza[1], Heba H. Al-Hayani[2]

Control and Systems Engineering Department, University of Technology, Baghdad

Email: drekhlaskadum@gmail.com[1], heba_alhayani@yahoo.com[2]

Abstract *Wireless sensor network (WSNs) consists of many tiny sensor nodes that can communicate with each other to perform sensing and data processing. Sensor nodes have small, portable batteries integrated into the sensor chips cannot be re-charged easily. Energy reduction is one of the major problems in the design of a WSN. An important factor affecting energy consumption is hop distance .Multi base stations(BS) can be used to dramatically reduce the energy consumption of sensor nodes. In this paper simulation Low Energy Adaptive Cluster Hierarchy (LEACH) protocol in MATLAB with single and multi BS and shown the effect of additional BS in the network performances. The proposed method achieves significant improvement in term of network lifespan and provides enhanced energy performance for WSNs.*

Keywords: *Wireless sensor network (WSN), LEACH protocol, base station (BS)*

1 Introduction

A wireless sensor network (WSN) typically consists of large number of homogenous or heterogeneous wireless sensor node (as shown in figure 1) located over a geographic area and has little or no infrastructure. The "wireless sensor node" term is for devices that use low power and are equipped with one or more sensors, a radio unit , processor , an optional actuator and power supply , sensor nodes are equipped with small, often irreplaceable batteries with limited power capacities .Sensor nodes in WSNs gather data about the conditions in which they are located and transform their data into electronic signals [1].The electronic signals are transmitted as radio waves to the base station (BS) (also called sink). It can be either a mobile or a fixed node that connects the sensor network to other types of network such as internet or satellite where a reported data is accessible to the user [2].

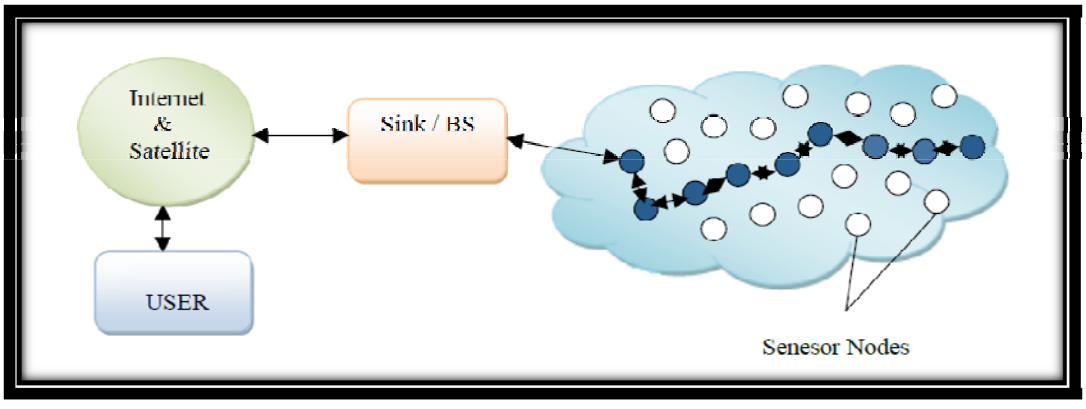

Figure 1: General overview of WSNs [3]

WSN applications can be classified into two categories: monitoring and tracking. Monitoring applications comprise indoor or outdoor environmental monitoring, health and wellness monitoring, power monitoring, inventory location monitoring, factory and process automation, and seismic and structural monitoring. Tracking applications include tracking objects, animals, humans, and vehicles [4].

The BS is of such significance to the network and without BS the network is useless. It is not limited to being located at the periphery of the sensor network. It could also be located somewhere within the sensor grid, and differs from traditional WSNs nodes in two ways: 1) The BS is *less* energy constrained than other nodes in the network, and 2) the BS provides the link to the outside of the network for all nodes inside the network. A BS that is *less* energy constrained refers to the notion that it is not limited by energy and it has enough energy to handle all the communications from the network until the last node in the SNs dies. [2, 5]. This means it has a battery energy level a few magnitudes greater than SNs, or it has an external source of power. We use this assumption to preclude the possibility that the BS is the limiting factor in the network[6].

SNs have limited battery lifetime. Usually their battery cannot be replaced and recharged due to area off their deployment. In order to operate the WSNs more efficiently and to maximize the lifetime of the system, energy efficient deployment, circuits, architecture, algorithms and protocols are needed. Many researches are going in the field of energy optimization of WSN and many energy efficient routing protocols. Low energy adaptive clustering hierarchy (LEACH) protocol have been proposed, where the concept of clustering, cluster head(CH) and techniques like data aggregation and data fusion are used which help in increasing the efficiency of the network [7-9].

This paper focuses on LEACH protocol with: 1) a single BS and 2) a multi-BS scenario. The majority of existing research in WSNs generally includes the perspective of a single BS. Thus, it is important to extend WSNs concepts to a multi-BS framework and identify the resulting performance improvements by including an additional BS.

The paper is organized as follows: Section 2 consists of the brief description about the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. Section 3 describes System Model and Assumptions. Section 4 describes the implementation of the experiment. Section 5 simulation results along with comparisons are discussed. Finally, section 6 concludes the paper.

2. Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is [8, 10-12] the first and foremost single-hop clustering routing protocol for WSN; it saves a large amount of network energy in comparison with non-clustering algorithms. This protocol falls under hierarchal networks. It is self-organizing and is characterized as an adaptive clustering protocol which uses randomly distributes energy load among nodes. It is organize the nodes into cluster for each cluster, there is elected node called cluster head (CH) and the rest nodes called cluster member (CM) , as shown in figure 3 . LEACH down into rounds, each round has two phases: the setup phase and the steady - state phase.

2.1 Setup Phase

In this phase, clusters are formed and a CH is chosen for each cluster. Every sensor node (n) chooses a random number between 0 and 1. If this random number is less than a threshold value $T(n)$, the node becomes a cluster-head for the current round . $T(n)$ is defined as follows:

$$T(n) = \begin{cases} \dfrac{p}{1-p\left(r \bmod \left(\frac{1}{p}\right)\right)} & \text{if } n \in G \\ 0 & \text{other wise} \end{cases} \quad (1)$$

where

- p is the percentage CH to all the nodes,
- r is the current round and G is the set of nodes that have not been elected in the past $1/p$ rounds off election.

When $r = 0$, the possibility off each node becoming the CH is P. If any node becomes the CH node in the first r rounds, it can be no longer reelected in the future $(1/P - r)$ round which enhances the possibility of other nodes to become a CH. After $1/P$ rounds, all nodes have a possibility off P to be a CH once again, over and over again. A node is selected as a CH at random. The CH node broadcasts messages to the environment, and other nodes select a cluster to join in, subject to the intensity off the broadcasted messages they received, and then inform the corresponding CHs. A CH communicates with a sink node directly and the cluster members only communicate with the cluster head in their own cluster. When clusters are formed, each CH creates a TDMA schedule according to the number of nodes in the cluster. Each node sends their sensed data to its CH during its allocated transmission time in the TDMA.

2.2 Steady-State Phase

In the phase, all the non-CHs nodes start sensing data and send it to their CHs according to the TDMA schedule. The CH node compresses the received data and sends it to the BS. Communication is via direct-sequence spread spectrum and each cluster uses a unique spreading code to reduce inter-cluster interference. After certain period of time, the network again goes into the setup phase and enters another round of selecting CHs [8, 10, 11].

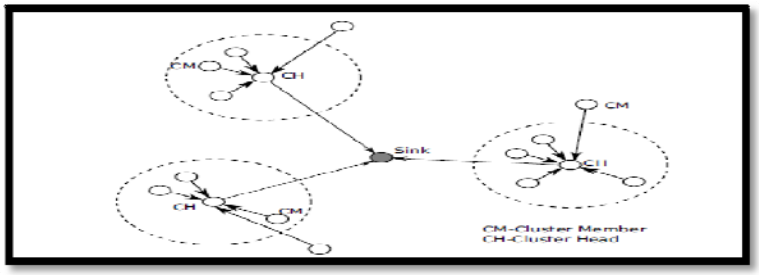

Figure 2: LEACH protocol [13]

3. System Model and Assumptions

3.1 Assumptions

The following assumptions are made for the new scheme:

- All nodes are homogenous and stationary after deployment.
- The BS stationary and has the information about the location off each node.
- Each sensor node generates one data packet per time unit to be transmitted to the BSs. For simplicity, we refer to each time unit as a round.
- Nodes are dispersed in a 2-dimensional space and cannot be recharged after deployment$_s$.
- Each node is assigned a unique identifier (ID).
- Each Sensor node has the same initial power.
- Energy off transmission depends on the distances (source to destination) and data sizes.
- The radio channel is symmetric i.e. the energy required to transmit a message from node M to node N is same as the energy required to transmit a message from node N to node M for a given SNR.
- The nodes do not cooperate with each other, not try to access the channel simultaneously and we consider a linear wireless network for our analysis.

3.2 Radio Energy Model

In this work, we uses the first order RF model to estimate the energy consumption of different nodes and the whole network lifetime .This model introduces the energy expended to send and receive *L-bit* message over a distance *d* taking into account free space propagation and multi path propagation models. The transmission energy in free space model is proportional to distance d^2, for multi path propagation model this energy is proportional to distance d^4 due to different paths that take the transmitted signal to reach the receiver[14]. The energy model for transmission and reception is shows in Figure 4.

The energy consumed to send data of *L* bit packet over a distance *d* from a node to a cluster head or a base station is calculated according to equation (2).

$$E_{Tx}(L,d) = E_{tx\text{-}elec}(L)+E_{tx\text{-}amp}(L,d) \quad (2)$$

We obtain the crossover distance *do* that defines the propagation transition from direct path to multipath model:

$$do= \sqrt{\frac{Efs}{Emp}} \quad (3)$$

The energy expended for free space propagation (where d < do) *ETx-fs* is described by:

$$E_{Tx\text{-}fs}(L,d) = E_{elec}.L + E_{fs} . L.d^2 \quad (4)$$

The energy expended for multi-path propagation(where d ≥ *do) ETx-mp* is given by:

$$E_{Tx\text{-}mp}(L,d) = E_{elec} . L + E_{mp} . L.d^4 \quad (5)$$

The energy expended to receive *L*-bit message is defined as[8]:

$$E_{Rx}(L)=E_{elec}.L \quad (6)$$

Where

- E_{elec} Energy consumed in electronic circuit to transmit or receive the signal L No. of bits in a packet
- E_{fs} Energy consumed by the amplifier to transmit at a shorter distance
- E_{mp} Energy consumed by the amplifier to transmit at a longer distance
- *d* Distance between transmitter and receiver

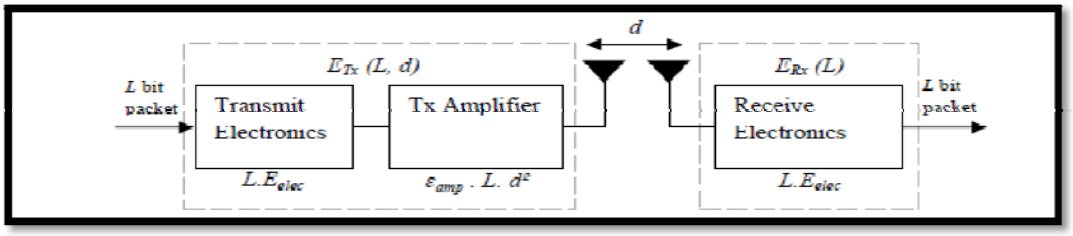

Figure 3: First order energy model [14]

4. Simulation

To evaluate the performance between LEACH with single and multi BS, we have performed in MATLAB (R2014a) when run for 4000 rounds with various random node placements. All nodes are homogenous (have the same initial power) and stationery after deployment. Table 1 shows simulation parameters used in this work. Our scenarios assume that BS to be placed far from the sensor network. Following this assumption, the single BS scenario employs the BS at (x, y) = (50m, −100 m), while the multi-BS simulations have the BS positioned at (x1, y1) = (50m, −100 m) and (x2, y2) = (50m, 150 m). The single BS and multi-BS WSNs are graphically shown in Figure 4 and Figure 5, respectively.

Our goals in conducting the simulation are as compare the performance of the single and multi BS in WSNs on the basis of energy dissipation and the lifetime of the network.

Average energy dissipated: This metric shows the average dissipation of energy per node over time in the network. Three factors are considered to be responsible for consuming the energy during data routing which are: data send, data receive and data aggregate.

Network lifetime: is the time from the starting of the experiment (turning all sensors on) until the moment when the first one died. We use term FND (first node dead), 10%, 50% and 80% for indicate the lifetime of network.

Table 1: Simulation parameter

Parameter	Value
Network size	50m × 50m
Base station 1 position	25m × -100m
Base station 2 position	25m × 150m
Number of nodes	100
Percentage of CH	0.05
Message size	2000 bit
Transmission and receiving energy	50 nJ/bit
Energy amplification for free space	10 pJ/bit/m^2
Energy amplification for multi path	0.0013 pJ/bit/m^2
Nodes initial energy	0.5J
Data aggregation energy	5 nJ/bit/message

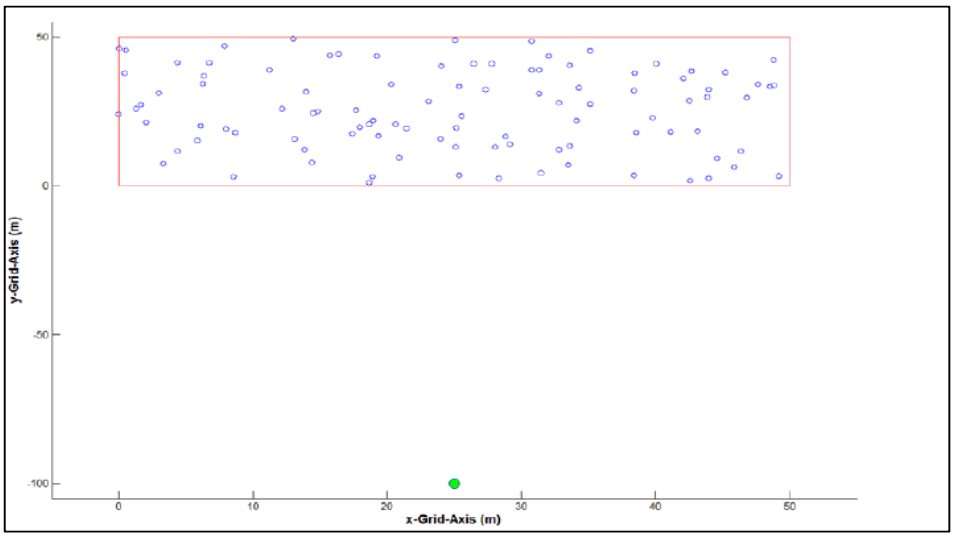

Figure 4: Single BS WSN

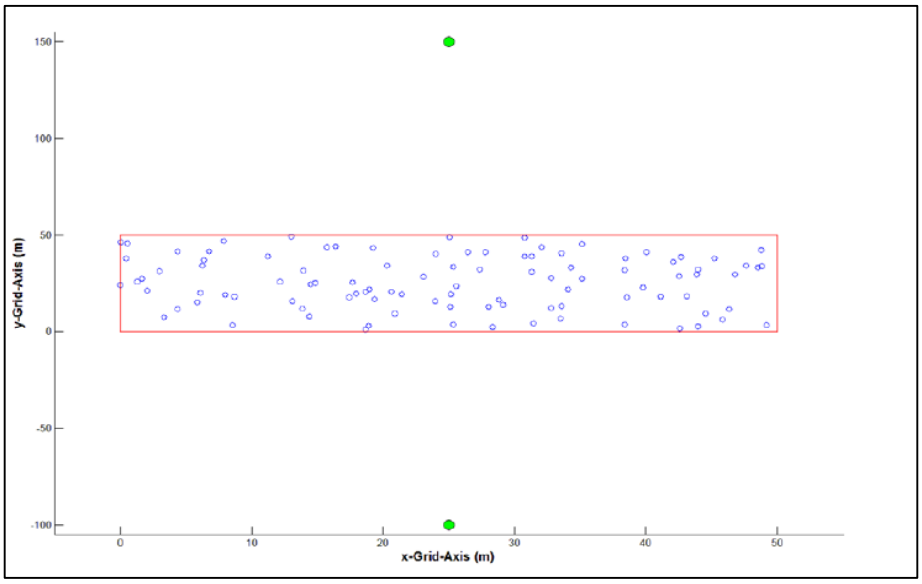

Figure 5: Multi BS WSN

5. Results

For single BS LEACH routing initiates LEACH clustering, and each node sends an *L*=2000 bit packet to the BS through the CH during each round. The CH aggregates all packets into a single 2000 bit packet for the round and performs the transmission to the BS. For multi BS, like single BS but the CH performs the transmission to the closer BS.

Fig. 6 shown total system energy of network per round all nodes has 0.5J initial energy, and total energy of 100 nodes is 50 J. Fig. 7 and table 2 shown the lifespan of the network per round. For the single BS the FND (first node dead), 10 %, 50 % and 80 % node dead occurs 1210, 1288, 1556 and 1877 rounds, respectively. For the multi BS the FND, 10 percent, 50 percent and 80 percent occur 1520, 1693, 1939 and 2090 rounds, respectively. Corresponding to a percent increase of 25.6%, 31.4%, 24.6% and 11.3%, respectively, when compared to the single BS die out for the same protocol. In the case of single BS the node far the BS required more hop distance while in the case of multi BS the hop distance for all node is less than other case. Consequently, the performed sensor network using the multi BS remains alive during more rounds.

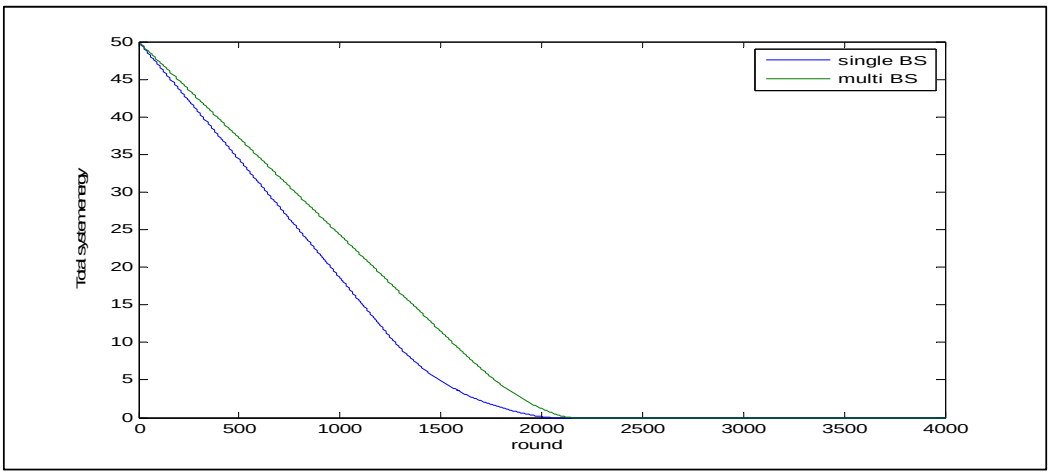

Figure 6: Total energy of the network versus transmission rounds for single and multi BS

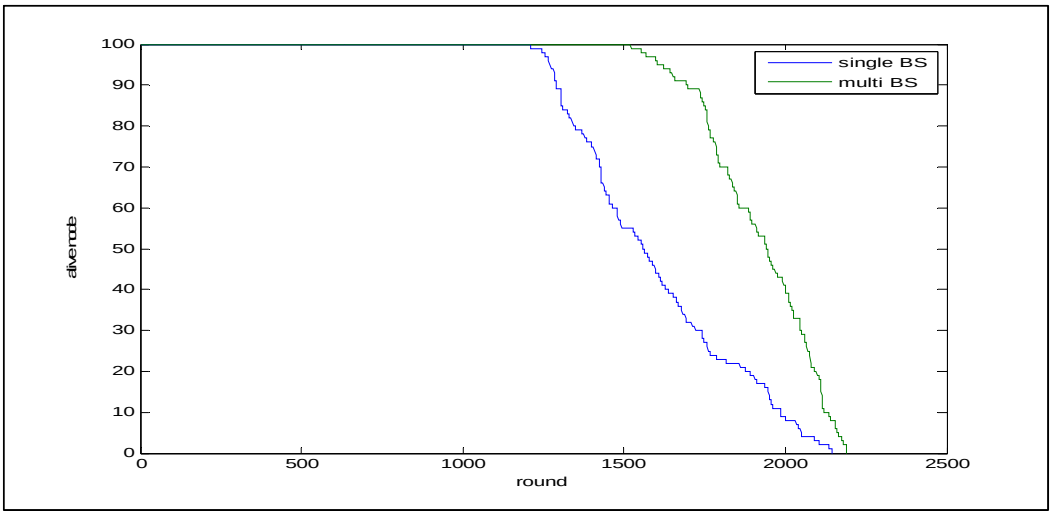

Figure 7**:** Total alive node of the network versus transmission rounds for single and multi BS

5. Conclusion

In this paper, we present and compare the performance of the single and multi BS with LEACH protocol in WSN on the basis of energy dissipation and the lifetime of the network. LEACH protocols using clustering algorithms that offer data aggregation for packet. The energy required to transmit a compressed message is less than if packets are not aggregated. Results of performed simulations reveal that the additional BS does significance improved the network performance more than single BS because the hop distance in the multi BS less than the single BS.

Table 2: Simulation results of alive node

	FND	**10% node dead**	**50% node dead**	**80% node dead**
LEACH with single BS	1210 rounds	1288 rounds	1556 rounds	1877 rounds
LEACH with multi BS	1520 rounds	1693 rounds	1939 rounds	2090 rounds

References

[1] R. Behrouz . Increasing Network Lifetime In Cluster Based Wireless Sensor Networks Via Fuzzy Logic, Master Thesis, Ryerson University, Canada, 2012.

[2] P.Sethi and N. Chauhan . Exploring the Feasibility of Mobile Agents in Sensor Networks in Non-Deterministic Environments. International Journal of Advancements in Technology, 1(9), 296-302, 2010.

[3] F. G. Nakamura, F. P. Quintao , G. C. Menezes, and G. R. Mateus . An optimal node scheduling for flat wireless sensor networks. Networking-ICN 2005, 475-482,2005.

[4] S. Zhang and H. Zhang . A review of wireless sensor networks and its applications, in Automation and Logistics (ICAL), International Conference on. 2012. IEEE,2012.

[5] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci . Wireless sensor networks: a survey. Computer networks, 38(4) , 393-422,2002.

[6] K . A. White. Tactical network load balancing in multi-gateway wireless sensor networks, Master Thesis, NAVAL POSTGRADUATE SCHOOL MONTEREY CA , 2013.

[7] J. Wang, Y. Niu, J. Cho and S. Lee . Analysis of energy consumption in direct transmission and multi-hop transmission for wireless sensor networks.in Signal-Image Technologies and Internet-Based System, 2007. SITIS'07. Third International IEEE Conference on. 2007. IEEE, 2007.

[8] W.B. Heinzelman , A.P. Chandrakasan and H. Balakrishnan .An application-specific protocol architecture for wireless microsensor networks . IEEE Transactions on wireless communications,1(4) , 660-670, 2002.

[9] W.R. Heinzelman, A. Chandrakasan and H. Balakrishnan.Energy-efficient communication protocol for wireless microsensor networks. in System sciences, Proceedings of the 33rd annual Hawaii international conference on IEEE, 2002.

[10] D. Verma, R. Jain and A. Shrivastava. Performance Analysis of LEACH and LEACH-CC Routing Protocol in Wireless Sensor Network. IUP Journal of Telecommunications,8(3), 45,2016.

[11] L. An, A. Li, L. Pang and G. He. Analysis and Comparison of Routing Protocol of Wireless Sensor Network. International Journal of Online Engineering, 12(10), 4-10,2016.

[12] A .Ihsan , K. Saghar and T. Fatima. Analysis of LEACH protocol (s) using formal verification. in Applied Sciences and Technology (IBCAST), 12th International Bhurban Conference on2015,IEEE,2015.

[13] A. K. Singh, S. Rajoriya, S. Nikhil, and T. K. Jain . Design constraint in single-hop and multi-hop wireless sensor network using different network model architecture. in Computing, Communication & Automation (ICCCA), International Conference on 2015, IEEE,2015.

[14] I.F.Akyildiz and M.C. Vuran. Wireless sensor networks. John Wiley & Sons,4 ,2010.