www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 4 Issue 7 July 2015, Page No. 13061-13066

Design Of Energy-Efficient Clustering Algorithm for Large Scale Wireless Sensor Networks

Sridevi H N[1] C K Raju[2]
Computer Science & Engineering
SSIT
Tumkur, India
sridevihn@gmail.com
Computer Science & Engineering
SSIT
Tumkur, India
ckrajussit@gmail.com

ABSTRACT- A wireless sensor network (WSN) is a network system comprised of spatially distributed devices using wireless sensor nodes with limited energy resources. The individual nodes are capable of sensing their environments, processing the information data locally, and sending data to one or more collection points in a WSN. That issue can be solve by using clustering algorithm as a solution to reduce energy consumption. The System implements a clustering method for entire networks. The nodes are organized into clusters. Within a cluster, nodes transmit data to cluster head (CH) without using . CHs transmit data to sink. In this paper, a new clustering algorithm, named PDKC, is proposed for wireless sensor networks based on node deployment knowledge. In PDKC , sensor node location is modelled by Gaussian probability distribution function instead of using GPSs or any other location-aware devices. Finally, we present a distributed implementation of the clustering method. Extensive simulations confirm that our method can reduce the number of transmissions significantly and shows corresponding time delay.

Keywords : Wireless sensor networks, clustering, energy efficient, coverage, data aggregation,PDKC

I. INTRODUCTION

Recent developments in wireless communications have provided low cost and small size sensor nodes [1].A wireless sensor network consists of thousands of limited resource sensor nodes, used to collect information from the surrounding environment. These sensor nodes are able to communicate with each other and also with base station (BS)[2]. Due to some constraints on the size and the cost of sensor nodes, they usually are equipped with limited and non rechargeable batteries; therefore, reducing the amount of energy dissipation is an important challenge in the network lifetime. To reduce energy consumption, unnecessary information should not be sent to the BS. Clustering is an effective scheme in reducing energy consumption and increasing the scalability of the WSNs. In this method the network is divided into some separate clusters. Each cluster has a cluster head (CH) and each sensor node belongs to a cluster to deliver the sensed data to its cluster head. Finally, each CH aggregates the received data and sends it to the BS. Since some sensor nodes are located around a special event similar data would be sent to the CH, aggregation mechanisms in the CH can reduce the amount of transmitted data to the BS. Hence, the energy consumption reduces significantly in the sensor nodes. Furthermore, [3] network coverage is another challenge especially in large scale WSNs such as military applications [4]. In such networks, it is important to cover the whole network area while decreasing the overlap between clusters [5]. In other words, decreasing the overlapping areas has a significant influence on the reduction of the energy dissipation In the clustering algorithm there are two kinds of communication , intra-cluster and inter-clusterIn intra-cluster, since the distance between CH and sensors are too short, the commutation is established by one or at most two hops. However, in inter-cluster communication the distance between CHs and BS may grow extremely. In previous researches [6], it has been shown that multi-hop communication between a data source and a data sink is usually more energy efficient than direct transmission. The main problem of this approach is that the sensors closer to the BS suffer from heavy relay traffic. Therefore, they die much sooner than other sensors, thus sense coverage of the network decreases. In the current paper, a clustering algorithm, namely an efficient Power consumption based on Deployment Knowledge for Cluster based WSNs (PDKC), is proposed in which both network coverage and energy consumption are considered as main factors. PDKC algorithm is based on deployment knowledge that improves the sensor node energy consumption and the network coverage simultaneously.

The proposed algorithm, however, benefits from sensor nodes deployment knowledge; sensor nodes do not require any GPS or other location aware devices. Additionally, they need not to be synchronized with each other; accordingly, their expenses and energy consumption are decreased [7]. In the proposed algorithm, selecting a CH is done according to some parameters including approximate sensor node position, residual energy, and sensor node degrees. In addition, in PDKC, the transmission range of each CH varies according to the distance between the CH and BS.

II. RELATED WORK

The first proposed clustering algorithm for WSN was LEACH[8]. The clustering operation in this method is done in two phases. In the first phase, named setup, some sensor nodes are randomly chosen as CHs in each round. In the latter, named steady-state, data is transmitted from nodes to the CH and CH sends the aggregated data to the BS. PEGASIS[9] is an extension of LEACH, in which all nodes are grouped into a chain and each node sends its data to the nearest neighbour. Only one sensor node is selected from that chain to transmit the aggregated data to the base station. Compared with LEACH, this algorithm decreases energy consumption of nodes significantly, but the data delay is much extensive. Therefore, the use of this protocol in large scale networks seems impossible. Some other algorithms try to balance energy consumption of the nodes by using equal clusters in the network. In[10] this system, the network area is divided into a set of equal squares and then a GPS-free scheme is used to get nodes deployment information. Nodes belonging to a same cell make a cluster and a new CH is selected in each round.USC[11] was the first algorithm proposed in order to balance energy consumption of the sensor nodes by forming unequal clusters. However, in the latter research, it was proved that this algorithm seems impractical to be used in the WSNs. Because the CHs are performed by some super nodes all the time and are deployed at pre-determined locations [12]. A clustering algorithm based on the highest degree is proposed in[13] this system. In this protocol, the node that has the most neighbours would be selected as CH.

Recent advances in wireless sensor networks have led to many new protocols specifically designed for sensor networks where energy awareness is an essential consideration. Most of the attention, however, has been given to the routing protocols since they might differ depending on the application and network architecture. This paper surveys recent routing protocols for sensor networks and presents a classification for the various approaches pursued. The three main categories explored in this paper are data-centric, hierarchical and location-based. Each routing protocol is described and discussed under the appropriate category. Moreover, protocols using contemporary methodologies such as network flow and QoS modeling are also discussed. The paper concludes with open research is advances in processor, memory and radio technology will enable small and cheap nodes capable of sensing, communication and computation. Networks of such nodes can coordinate to perform distributed sensing of environmental phenomena. In this paper, we explore the directed diffusion paradigm for such coordination. Directed diffusion is data centric in that all communication is for named data. All nodes in a directed diffusion-based network are application-aware. This enables diffusion to achieve energy savings by selecting empirically good paths and by caching and processing data in-network (e.g., data aggregation). We explore and evaluate the use of directed diffusion for a simple remote-surveillance sensor network analytically and experimentally. Our evaluation indicates that directed diffusion can achieve significant energy savings and can outperform idealized traditional schemes (e.g., omniscient multicast) under the investigated scenar Wireless distributed micro sensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications. In this we look at communication protocols, which can have significant impact on the overall energy dissipation of these networks. Based on our findings that the conventional protocols of direct transmission, minimum-transmission-energy, multi hop routing, and static clustering may not be optimal for sensor networks, we propose LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network.

LEACH uses localized coordination to enable scalability and robustness for dynamic networks, and incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. Simulations show that LEACH can achieve as much as a factor of 8 reduction in energy dissipation compared with conventional routing protocols. In addition, LEACH is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks we simulate Wireless sensor networks constitute the platform of a broad range of applications related to national security, surveillance, military, health care, and environmental monitoring .The sensor coverage problem has received increased attention recently, being considerably driven by recent advances in affordable and efficient integrated electronic devices. This problem is centred around a fundamental question: *How well do the sensors observe the physical space?* The coverage concept is subject to a wide range of interpretations due to a variety of sensors and their applications .Different coverage formulations have been proposed, based on the subject to be covered (area versus discrete points) and sensor deployment mechanism (random versus deterministic) as well as on other wireless sensor network properties (e.g. network connectivity and minimum energy consumption).In this article, we survey recent contributions addressing energy-efficient coverage problems in the context of static wireless sensor networks. We present various coverage formulations, their assumptions, as well as an overview of the solutions proposed.

III. DEPLOYMENT-BASED CLUSTERING ALGORITHM

As mentioned in the previous section, clustering is one of the important methods for reducing power consumption in sensor nodes sending data to the BS. Different methods for cluster-based WSNs have been proposed. Some of these methods make use of additional equipment, such as GPS or other location aware mechanisms. Using such equipment would increase the cost and the energy consumption in the sensor nodes. Besides, in all other proposed algorithms, the network coverage performance is low and they are considered to cover a small area, yet in most of applications the network area is so small [2]. This paper proposes a clustering algorithm, namely PDKC, for large scale network. While, in PDKC, the clustering algorithm requires sensor node deployment information, the sensor node doesn't need to have any additional equipment such as GPS. Firstly, in order to explain the proposed algorithm, the network model is presented, and then the clustering algorithm is discussed.

A. Network Model

In order to receive regional information, in most of applications, many sensor nodes are distributed in a wide area [6, 7]. In WSNs sensor nodes are usually distributed byan airplane. If the distribution of the sensor nodes is done uniformly, sensor nodes can be located in each area with the same probability. If so, there isn't any deployment knowledge available about the sensor node resident point. In the literature, it has been proved that having deployment

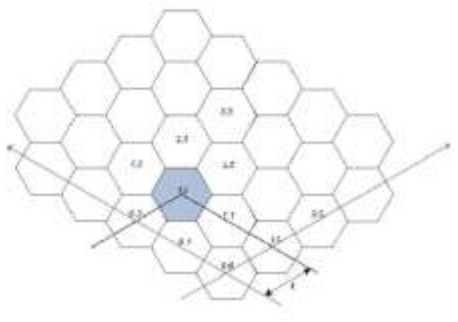
knowledge invigorates algorithm performance. In the proposed protocol, since no location aware device is used in sensor nodes, deployment knowledge is modelled using a Gaussian probability distribution function (Pdf) [14]. On the other hand, former proposed clustering algorithms use a

uniform pdf.In the proposed scheme, the network area is divided int non-overlapping hexagonal cells, and the sensor nodes are allocated in groups into these cells. The centre of a cell is defined as the deployment point of the sensor nodes allocated to that specific cell. Fig. 1, shows the division of the network into hexagonal cells. The distance between adjacent cell deployment points is L. Each cell in the proposed scheme has a pair of credentials (i, j) which are the cell position. Using two-dimensional Cartesian coordinates and assuming that the deployment point of cell Ci, j is (xi, yi); [14] the pdf of the sensor node resident points can be formulated as:

f;,i(X,Ylk ∊ Ci,i) = f(x - xi'Y - Yi)
= _1_e- [(X- Xi)2+(Y - Yi)21/ 2u 2 (1)
2nu2
Assuming identical pdfs for every group of sensor nodes
fk(x,YlkC ∈ (i,j)) can be used i.nstead of

If(x,Ylk ∈ C(i,j))

As in [14-16], in the proposed scheme it is assumed that the routing protocol delivers the transmitted data to the correct destinations. In the proposed scheme, the network area is divided into non-overlapping hexagonal cells, and the sensor nodes are allocated in groups into these cells. The centre of a cell is defined as the deployment point of the sensor nodes allocated to that specific cell. In other words, in the proposed algorithm not only is the deployment knowledge considered, but also the uniform density of the sensor nodes in the network area becomes very important. However, by choosing an appropriate amount for standard deviation in Gaussian distribution this goal becomes achievable.



--

Fig. 1. A two-dimensional WSN with adjacent deployment point distance L.

With a Gaussian distribution, the distance between the resident and deployment points is less than *30'* with the probability of 0.9987, where *0'* is the standard deviation [15].In addition, if the distance between deployment points in two cells is more than *60'* , there is little chance that two sensor nodes, each belonging to one of these cells, be adjacent [15],[16].As mentioned, the distribution of sensor nodes in each cell is modelled by a Gaussian probability distribution around the deployment point. Although using Gaussian distribution would allow having information about the resident point of the sensor nodes, yet it is preferable to have uniform distribution over the whole network.

B. Energy Consumption Model

In this paper, the energy consumption model is based on the proposed model in DEECIC algorithm [9]. In this model ,the multipath fading channel is used when the distance between the sender and the receiver is more than threshold d_O; otherwise the free space model is used. Therefore, in order to transmit an L-bit message with the distance d there would be:

$$\varepsilon_{Tx}(L,d) = \begin{cases} L \times E_{elec} + L \times \varepsilon_{fs} \times d^2 & d < d_0 \\ L \times \varepsilon_{elec} + L \times \varepsilon_{mp} \times d^4 & d \geq d_0 \end{cases}$$

Where *Ee1ec* is the energy dissipated per bit to run the transmitter or the receiver circuit, *Efs* or *Emp* is the energy dissipated per bit to run the transmit amplifier. To receive this message, the required amount of energy would be:

ERX(L) =L X *Ee1ec (4)*

EDA Is amount of energy for data aggregation, thus the energy dissipated for aggregating m-bit data is as follow:

EA(m,L) =m X *Lx EDA (5)*

The cluster head can always aggregate the data gathered from its members into a single length-fixed packet.C.

C. PDKC Algorithm Description

The proposed clustering algorithm considers the energy consumption besides the network coverage. In the previous works just one of these factors was subjected. If both parameters are considered, the clustering algorithm would be more realistic. The aim of PDKC is to cover the whole network by having the constant number of cluster heads, an then having executed the algorithm, each node becomes a member of only one cluster. According to the sensor node distribution model in the network, this approach will result in an appropriate coverage in the whole network. In the proposed algorithm each node sends its data with at most 2 hops to its corresponding cluster head. Therefore, sensor nodes that cannot communicate to the CH directly can profit from an intermediate sensor node to communicate indirectly with its CH. The transmitted data to a cluster head consists of the node identity and the received in format ion from the environment. Hence, the CH can recognize the source of the received message either directly or indirectly. Consequently, in the proposed algorithm, without imposing significant overhead to the nodes, the network area becomes expandable. In PDKC, each sensor node has a three dimensional identity, namely that of (ij,k). While the first two dimensions, (ij), specify the cell of the sensor node the last one is the sensor node identity in the cell. In each round a new cluster head is selected. In order to select the appropriate new cluster head, sensor nodes belonging to a cell must send some information to the current cluster head. Since, in PDKC, the number of sensor node degree is a criterion of CH selection, the nodes located in the denser parts of the network would be more likely to be selected as cluster head. In the proposed algorithm each sensor node can have 3 statuses; head of a cluster, member of a cluster, and/or non-member of a cluster. In the following subsections, more detail of PDKC algorithm is presented.

1) Cluster Formation

In the first step of the algorithm, after deployment of the sensor nodes to the network, BS broadcasts a "Hello" message to the entire network in order to estimate the distance of each node from the BS. This message contains the primary energy that the BS needs to send the message to all deployed sensor nodes. Having received the message, each node can estimate its distance from the BS by comparing the amount of the received signal energy to the primary energy level received in the message. Suppose during the execution of the algorithm all sensor nodes are awake in the network. Moreover, at the beginning of each round, every node broadcasts an "update" message to the network to indicate its existence to the neighbors. The TTL of the broadcasted message is one. Therefore, sensor nodes that have received the update message do not relay it. The reason behind sending this message is that each node computes its degree. Therefore, the nodes' degree is calculated as follows[9]:

$$NodeDegree\ S_i = count\ s_j\ dist\ s_i < R_c, s_j \in \mathbb{S}, s_i \neq s_i$$

Where Sj is a neighbour of *Si* in the wireless transmission range of *Si (Rc)'*After sending "Update" messages at the beginning of each CH selecting round, each node sends a unicast message, called feature message, including its identity, residual energy, and degree to its cluster head or to the virtual cluster head which will be described in the following. Then each CH will select two sensors nodes with the highest degree based on received feature messages. Afterward, one of them with the highest level of residual energy is selected as a new cluster head. This decision is announced to the new cluster head by a unicast message. Then, the new cluster head broadcasts a message to the network with TTL equal to one, called advertise message. In this message, the new CH advertises himself to its neighbors. Also, the residual energy of the CH and the estimated distance between the node and the BS is announced to the sensor nodes by the advertise message.

Therefore, each node that receives the advertise message can decide which CH is suitable. The selection of an appropriate cluster head is done based on the residual energy and the distance of the CH to the BS. Therefore, each sensor node selects two CHs with the highest residual energy. Then the sensor node selects the one that is the closest to the BS as its cluster head.Each sensor node that selects its cluster head broadcasts a message with TTL equal to one to inform its neighbors about the new cluster head. Therefore, some sensor nodes that have not received any advertise message get informed about the nearest cluster head. Hence, the sensor node with at most two hop distances from a cluster head can select it as CH. By this operation, almost all sensor nodes can select at least one cluster head and the probability of uncovered area will decrease extremely. The selection of cluster head with two hop distance is similar to one hop distance. It is mentioned that if two cluster heads have equal estimated distance from the BS, one of them is selected randomly.As mention before, at the begging of each round, the feature message is sent to the cluster head or virtual cluster head. In all rounds except for the first one, each sensor node knows its cluster head. In the first round, no cluster head is introduced to the network. Therefore, in this round a special sensor node in each cell is considered as a cluster head for that cell. Assume a sensor node with identity (i, j, 0) is considered as a virtual cluster head for cell (i, j).Consequently, this sensor node is responsible for the new cluster head selection when sensor nodes are deployed to the network.

2) Algorithm Specification

According to network distribution model, nodes distribution models, and clustering method the proposed algorithm enjoys the following specifications:

• In PDKC, the clustering procedure is distributed thoroughly, and each sensor node sends some information to the neighboring sensor nodes. Since the algorithm is distributed, it does not cope with some challenges in the centralized algorithm.

• PDKC algorithm does not need the initial time synchronization. As mentioned before, in the proposed algorithm, each sensor node can make its own decisions based on the received information independently from other sensor nodes.

• PDKC algorithm is scalable regardless of network size and the number of deployed sensor nodes in the network

Algorithm for cluster head selection

1.Emax = 0
2.for every Ni, where i ε 1 to n
3.Broadcast available energy Ei
4.End for
5.for each Ni, i ε 1 to n
6.Compare Ei and Emax
i.If Ei>Emax
7.Ei = Emax
8.Nmax = Ni
iv.Ni broadcasts status to the network as CHnode
v.Ni = clusterhead

IV SYSTEM IMPLEMENTATION

The System implements a clustering method that uses k-Means clustering CS for entire networks. The nodes are organized into cluster . The system first propose an analytical model that studies the relationship between the size of clusters and number of transmissions in the hybrid CS method, aiming at finding the optimal size of clusters that can lead to minimum number of transmissions. Then, system proposes a centralized clustering algorithm based on the results obtained from the analytical model. To reduce energy consumption, unnecessary information should not be sent to the BS. It has been proved that clustering is an effective scheme in reducing energy consumption and increasing the scalability of the WSNs. In this method the network is divided into some separate clusters. Each cluster has a cluster head (CH) and each sensor node belongs to cluster to deliver the sensed data to its cluster head. Finally, each CH aggregates the received data and sends it to the BS.

It consists of 4 modules

Service provider:

In this module, the service provider will browse the data file and then send to the particular receivers. Service provider will send their data file to router and router will connect to clusters, in a cluster highest energy sensor node will be activated and send to particular receiver (A, B, C…). And if any attacker will change the energy of the particular sensor node, then service provider will reassign the energy for sensor node.

Router

The Router manages a multiple clusters (cluster1, cluster2, cluster3, and cluster4) to provide data storage service. In cluster n-number of nodes (n1, n2, n3, n4…) are present, and in a cluster the sensor node which have more energy considered as a cluster head and it will communicate first. In a router service provider can view the node details, view routing path, view time delay and view attackers. Router will accept the file from the service provider, the cluster head will select first and it size will reduced according to the file size, then next time when we send the file, the other node will be cluster head. Similarly, the cluster head will select different node based on highest energy. The time delay will be calculated based on the routing delay.

Cluster

In cluster n-number nodes are present and the clusters are communicates with every clusters (cluster1, cluster2, cluster3 and cluster4).In a cluster the sensor node which have more energy considered as a cluster head. The service provider will assign the energy for each & every node. The service provider will upload the data file to the router; in a router clusters are activated and the cluster-based networks, to select the highest energy sensor nodes, and send to particular receivers.

Receiver (End User)

In this module, the receiver can receive the data file from the service provider via router. The receivers receive the file by without changing the File Contents. Users may receive particular data files within the network only.

Attacker

Attacker is one who is injecting the fake energy to the corresponding sensor nodes. The attacker decries the energy to the particular sensor node. After attacking the nodes, energy will be changed in a router.

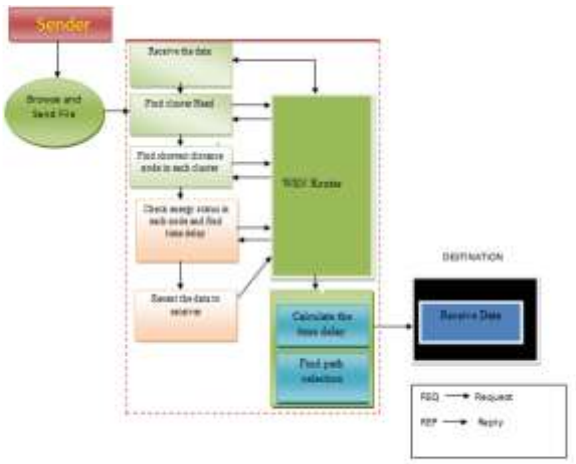


Fig 2 System Architecture

Fig 2 The System implements a clustering method that uses k-Means clustering CS for entire networks. The nodes are organized into cluste . The system first propose an analytical model that studies the relationship between the size of clusters and number of transmissions in the hybrid CS method, aiming at finding the optimal size of clusters that can lead to minimum number of transmissions. Then, system proposes a centralized clustering algorithm based on the results obtained from the analytical model.

V.RESULTS

File Name	Destination	Uploaded time	Time Delay
[illegible]	Dest A	[illegible]	[illegible]
[illegible]	Dest A	20/05/2015	[illegible]
[illegible]	Dest A	[illegible]	[illegible]
[illegible]	Dest A	11/06/2015	202881300
[illegible]	Dest A	11/06/2015	[illegible]
g.java	Dest A	[illegible]	[illegible]

Fig 3 Time delay

Fig 3 Shows the time delay taken to transfer the data. In cluster n-number nodes are present and the clusters are communicates with every clusters (cluster1, cluster2, cluster3 and cluster4).In a cluster the sensor node which have more energy considered as a cluster head. The service provider will assign the energy for each & every node. The service provider will upload the data file to the router; in a router clusters are activated and the cluster-based networks, to select the highest energy sensor nodes, and send to particular receivers.

Fig 4 Graph of time delay

V. CONCLUSIONS AND FUTURE WORK

In this paper a distributed energy efficient clustering algorithm, namely PDKC, based on deployment knowledge was proposed. The deployment knowledge was modeled based on Gaussian probability distribution function instead of using any location aware device such as GPS. In the proposed algorithm, the network has been divided in to hexagonal cells. The cluster head was selected based on the residual energy, node degree and deployment knowledge. Simulation results indicate that PDKC algorithm improves network coverage and prolongs network lifetime in comparison with LEACH, EEUC and EEBCDA especially for large-scale-networks

REFERENCES

[1] A Kemal and Y. Mohamed, "A survey on routing protocols for wireless sensor networks," Department of Computer Science and Electrical Engineering,University of Maryland, USA, 2003.
[2] C. Intanagonwiwat, R. Govindan, D. Estrin and J. Heidemann.t'Directed Diffusion for Wireless Sensor Networking ,*IEEE Trans. Networking,* vol. 11, no. 1,2003.
[3] M. Younis, M. Youssef and K. Arisha, "Energy-aware management in cluster-based sensor networks," *Computer Networks* 43 (5) *(2003)* 649-668.
[4] M.T. Thai, F. Wang and D. Du, "Coverage problems in wireless sensor networks design and analysis,"*International Journal of Sensor Networks* 3 (3) *(2008) 191-200.*
[5] M. Cardei and J. Wu, "Energy-efficient coverage problems in wireless ad hoc sensor networks", *Computer Communications Journal* 29 (4) *(2006) 413-420.*
[6] M. Ye, C. Li, G. Chen and J. Wu, "An energy efficient clustering scheme in wireless sensor networks," Ad Hoc & Sensor WirelessNetworks, 2006, 3, p. 99-119.
[7] Z. Liu, Q. Zheng, L. Xue and X. Guan, "A distributed energy-efficient clustering algorithm with improved coverage in wireless

sensor networks," In *Future Generation Computer Systems Journal*, Vol. 28, p.780-790, 2011.

[8] W. Heinzelman, A Chandrakasan and H. Balakrishnan, "Energyefficient communication protocol for wireless micro-sensor networks". In Proc of*IEEE Confon System Sciences*, 2000, p. 30053014.

[9] AP. Chandrakasan, AC. Smith and W.B. Heinzelman, "An application specific protocol architecture for wireless microsensor networks", *IEEE Transaction on Wireless Communications 1(4) (2004) 660--669.*

[10] J.N. Al-Karaki, R. Ul-Mustafa and AE. Kamal. "Data aggregation in wireless sensor networks-exact and approximate algorithms," In *Procof Workshop on High Performance Switching and Routing, 2004*, p. 241-245.

[11] J. Yuea , W. Zhang, W. Xiao, D. Tang and J. Tang. "Energy Efficient and Balanced Cluster-Based Data Aggregation Algorithm for Wireless Sensor Networks". Science and Technology on Information Systems Engineering Laboratory, National University of Defense Technology Changsha-410073, China.

[12] S. Soro, W.B. Heinzelman. "Prolonging the lifetime of wireless sensor networks via unequal clustering," In *Proc of IEEE Parallel and Distributed Processing Symposium, 2005*, p. 1-8.

[13] M. Gerla and IT.-C. Tsai, "Multicluster, mobile, multimedia radio network," *Wireless Networks*, vol.l, no. 3, 1995, pp. 255-265.

[14] A Fanian, M. Berenjkoub, H. Saidi, T.A. Gulliver, "A High Performance and Intrinsically Secure Key Establishment Protocol forWireless Sensor Networks", *Computer Networks Vol.* 55. *Issue* 8. 1 *June2011,Pages 1849-1863.*

[15] W. Du, J. Deng, Y.S. Han, S. Chen, and P.K. Varshney, "A Key Management Scheme for Wireless Sensor Networks Using Deployment Knowledge," in *Proc. IEEE Conf. on Computer Communications.* (INFOCOM), pp. 586-597, Mar. 2004.

[16] M. Ramkumar and N. Memon, "An Efficient Random Key Predistribution Scheme," in *Proc. IEEE Global Telecommunication. Conference* (GWBECOM), pp. 2218-2223, Dec. 2004.