International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Energy Efficient Cluster Head Selection in Wireless Sensor Networks

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Abstract: ***Wireless sensor network consists of several distributed sensor nodes. It is used for several military applications, environmental applications and health related applications. However, a WSN is a power constrained system, since sensors nodes have shorten lifespan because they run on limited power batteries. The lifespan of sensor network depends on battery unit. In WSN, Energy consumption is one of the most crucial design issues. It is essential to design efficient routing protocol for increase the lifetime of the sensor nodes. LEACH (Low Energy Adaptive Clustering Hierarchy) protocol motivates most of the research in energy efficient data gathering in data centric applications of WSN. It allows the rotation of cluster head role among the sensor nodes and tries to distribute the energy consumption over the network. The recent research based on LEACH-B routing protocol. It saves energy consumption by ensuring that the clusters are balanced. This exiting work has limitation that replaces the cluster head after completion of each round. A proposed approach reduced the amount of cluster head and replacement cost. By decreasing this cost, it increase network lifetime compared to existing protocol.***

Keywords: WSN, CH, LEACH, LEACH-B

1. Introduction

Wireless Sensor Network is composed of large number of sensor nodes, which are densely, deploy in unprotected environment. There is lot of research going on because of its wide applications in the field of civilian applications, defense security and medical research. In Wireless Sensor Network, there are various issues such as deployment issues and routing issues of WSNs. Wireless sensors networks (WSNs) have the advantage which is ability to operate unattended in abrasive environments in which contemporary human-in-the-loop monitoring schemes are risky, inefficient and sometimes infeasible. Therefore, sensors are deployed randomly in the area of interest by a relatively uncontrolled means, e.g. dropped by a helicopter, and to collectively form a network in an ad-hoc manner [1, 2].

Since WSNs consist of battery-powered devices, the energy efficient network protocols must be designed. Due to large network size, limited power supply, and inaccessible remote deployment environment, the WSN-based protocols are different from the traditional wireless protocols.

Wireless Sensor Networks (WSN) is an active research area in today computer science and telecommunication. The development of clustered sensor networks has recently been shown to decrease system delay, save energy while performing data aggregation and increase system throughput [4]. These are strong motivational points behind selecting LEACH as the baseline protocol for the analytical study. Also LEACH has a few but very significant disadvantages like it assumes all the nodes to have same energy, which is not the case always in real-time problems, its cannot be applied for mobile nodes, failure of cluster-heads creates a lot of problems and it does not take into account that the systems might have multiple base stations.

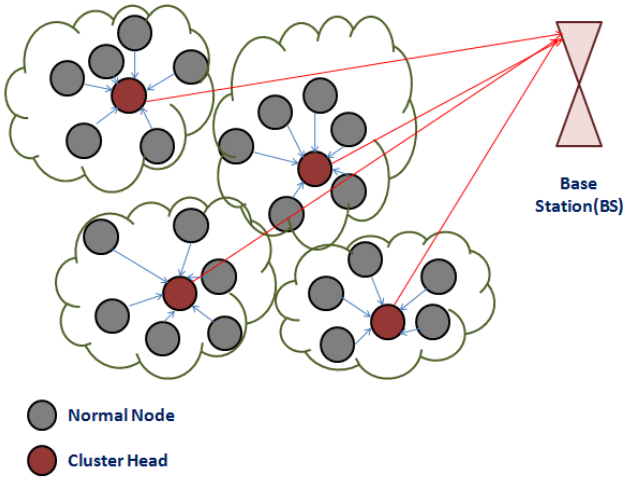

Figure 1: Cluster protocol model in WSNs

In a wireless sensor network, Cluster is a group of sensor nodes in large scale sensor network [8]. In each cluster, one node play role of Cluster Head (CH) which collect the data transmitted by normal node of its cluster.

The paper is organized as follows: Section 2 describes applications and limitations of sensor network. Section 3 describes various existing methods for energy efficient cluster head selection in wireless sensor networks. Section 4 describes proposed method. Section 5 describes simulation and results. Finally conclusion is presented in section 6.

2. Application and Limitation of Sensor Network

A few examples of the applications are as follows [3]:
(1) Area monitoring application
(2) Environmental application
(3) Health application
(4) Industrial application

Some limitations of the sensor network are as follows:
(1) Lack of a priori knowledge of post-deployment position.
(2) Adversary can capture nodes.
(3) Limited bandwidth and transmission power.
(4) Unreliable Communication
(5) Unattended after deployment
(6) Remotely managed

3. Related Work

In this section we have presented several existing methods in the literature for energy efficient cluster head selection in wireless sensor network.

3.1 Low Energy Adaptive Clustering Hierarchy [5]

Low Energy Adaptive Clustering Hierarchy (LEACH) is a cluster based protocol. It organizes nodes into clusters with one node from each cluster serving as a cluster-head (CH). LEACH randomly selects some predetermined number of nodes as cluster heads. CHs then advertise CH claim packets and other normal nodes join one of those cluster heads whose signal they found strongest. In this way a cluster is formed. The CH then makes a Time Class Multiple Access (TDMA) schedule for the nodes under its cluster. The communication between different clusters is done through CHs in a Code Division Multiple Access (CDMA) manner. The CHs collect the data from normal nodes of their clusters and aggregate it before sending it to the other CHs or base station (BS). After some predetermined time lapse, the cluster formation step is repeated so that different nodes are given a chance to become CHs and energy consumption is uniformly distributed.

LEACH operation is broken into rounds, with each round having a set-up phase and a steady state phase.

Set-up phase: Each normal node decides whether or not to be a cluster-head for current round based on its residual energy and a globally known desired percentage of cluster heads. Each node electing itself as a cluster-head broadcasts CH advertisement message.

Steady-state phase: Each cluster-head waits to receive data from all nodes in its cluster and then sends the aggregated or compressed result (report message) back to a BS.

Some limitations of the LEACH are as follow:
(1) Due to random selection, cluster head may be elected in one area leaving other area unattended.
(2) Each cluster head directly communicate with the base station that is not efficient if the transmission distance is large.
(3) For every round new cluster head is selected which consumes more energy and decreasing the network life time.

3.2 Hybrid Energy-Efficient Distributed Clustering [6]

HEED considers a hybrid of energy and communication cost when selecting CHs. Unlike LEACH, it does not select cluster head randomly. Only sensors nodes that have a high residual energy can become cell-head nodes. HEED has three main characteristics:

1) The probability that two nodes within each other's transmission range becoming CHs is small. Unlike LEACH, this means that CHs are well distributed in the network.
2) Energy consumption is not assumed to be uniform for all the nodes.
3) For a given sensor's transmission range, the probability of CH selection can be adjusted to ensure inter-CH connectivity.

3.3 Random competition based clustering (RCC) [7]

The RCC algorithm applies the First Declaration Wins rule, in which any node can ''govern'' the rest of the nodes in its radio coverage if it is the first to claim being a CH. After hearing, neighboring nodes join its cluster as member. To maintain clusters, every CH broadcast a CH claim packet periodically. Since there is a time delay between broadcasting a claim packet and receiving it, concurrent broadcast can possibly create a conflict. To avoid such a problem RCC explicitly employs a random timer and uses the node ID for arbitration. Each node reset its random time value, every time before broadcasting its CH claim packet. During this random time if it receives CH claim packet from another node, it simply ceases the transmission of its CH claim. Since random timer is not a complete solution, RCC resolve further problems by using the node ID. If the conflict persists, node having lower ID will become the CH. RCC is more stable than conventional clustering schemes.

3.4 PEGASIS: Power-Efficient Gathering in Sensor Information System [8]

PEGASIS is a chain based protocol provides improvement over LEACH algorithms. In PEGASIS, each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. Using greedy algorithm, the nodes will be organized to form a chain, after that BS can compute this chain and broadcast it to all the sensor nodes. Energy saving in PEGASIS over LEACH takes place by many stages: First, in the local data gathering, the distances that most of the sensor nodes transmit are much less compared to transmitting to a cluster-head in LEACH. Second, only one node transmits to the BS in each round of communication. PEGASIS outperforms LEACH by limiting the number of transmissions, eliminating the overhead of dynamic.

3.5 Energy Efficient Chain Based Routing [9]

The proposed protocol organizes sensor nodes as a set of horizontal chains and a vertical chain. In each chain, a node is selected as chain head. For selecting the chain heads in horizontal chains, EECBR considers residual energy of nodes and distance of nodes from the header of upper level. In each horizontal chain, sensor nodes transmit their data to their own chain head based on chain routing mechanism. EECBR also adopts a chain based data transmission mechanism for sending data packets from the chain heads to the base station.

3.6 Distance Based Cluster Head Selection Method [10]

The author [10] has proposed an algorithm that selects cluster head as per the following algorithm.
Step1. Let we have a set S of n nodes in a cluster viz.
Step2. Calculate the distance of one node to all nodes.
Step3. Calculate the sum of all distance from one to all nodes.
Step4. Calculate distance from BS to each node for all nodes.
Step5. Select the cluster head based on all NDBS values.

3.7 EECS: Energy Efficient Clustering Schemes [11]

In EECS, cluster formation is different from LEACH protocol. In LEACH protocol cluster formation takes place on the basis of a minimum distance of nodes to their corresponding cluster head. In EECS, dynamic sizing of clusters takes place which is based on cluster distance from the base station. The results are an algorithm that addresses the problem that clusters at a greater distance from the sink requires more energy for transmission than those that are closer. Ultimately it provides equal distribution of energy in the networks, resulting in network lifetime. Thus main advantage of this algorithm is the full connectivity can be achieved for a longer duration. So we can say it provides reliable sensing capabilities at a larger range of networks for a longer period of time. It provides a 35 percent improvement in network life time over LEACH algorithm.

3.8 MST-PSO: Minimum Spanning Tree-PSO [12]

Authors proposed a minimum spanning tree-PSO based clustering algorithm of the weighted graph of the WSNs. The optimized route between the nodes and its cluster heads is searched from the entire optimal tree on the basis of energy consumption. Election of cluster head is based on the energy available to nodes and Euclidean distance to its neighbor node in the optimal tree. Others have concluded that network life time does not depend on the base station location or residual energy of the node. Once the topology decided to then network life time becomes almost settled. Author's shows two techniques for improving network life time: reduce the startup energy consumption of the transmitter and receiver, and optimized the network topology.

3.9 LEACH-B [13]

3.9.1 LEACH-B Algorithm

LEACH-B (Balanced) which proposes an enhanced version of LEACH by finding the number of CHs which are near optimal. In LEACH-B, there is a second stage for selecting CHs through considering the residual energy of candidate nodes to become CHs, which modifies the number of CH sat the set up phase considering the node's residual energy. This protocol can save energy consumption by ensuring that the clusters are balanced. The optimal number of CHs is between 3 and 5 from total 100 nodes (3% - 5%).

LEACH-B works similar to LEACH by selecting a random number between 0 and 1 and calculating the threshold value . However, LEACH-B introduced another selection stage: All candidate CHs that are elected will be ordered descending according to their residual energy, and only (n*p) of them, (where n is total number of sensor nodes, and p is the percentage of CHs) will be considered as CH and the remaining candidate and will resume their normal node role. By doing that, LEACH-B guarantees the optimal number of CHs. Simulation results of LEACH-B shows an enhancement of lifetime compared to the original LEACH.

3.9.2 Problems of LEACH-B Protocol

Cluster head selection adopted by LEACH-B [7], has a constant number of clusters and balanced cluster distribution protocol, so its energy dissipation is balanced and near-minimal in contrast to the huge fluctuation in LEACH [5] protocol. However there are some improvements to be done in the LEACH-B protocol.

Cluster head selection adopted by LEACH-B [13], replace the cluster head after completion of each round. Energy consumption increases as the cluster head replacement increases (message transmission increases).

4. Proposed Work

In consideration of the defect of LEACH-B, as description above, we propose an Energy Efficient Cluster Head Selection Protocol for wireless sensor network to reduce the amount of cluster head selection and replacement cost and minimize energy consumption.

4.1 First Selection of the Cluster Heads

At first time, decision of CH selection is made by the node choosing random number as per LEACH [5]. The BS broadcasts the unique IDs of the newly selected cluster heads, and the nodes use this information to form and enter a cluster. Each cluster head creates a TDMA schedule and broadcast this schedule to all other nodes in its cluster. The node sends data within its allocated time. Each cluster head aggregate the data and finally aggregated data reaches to the base station.

Furthermore, this new protocol achieves the reduction of energy consumption. Figure 2 shows the flow chart of the second selection of cluster head.

4.2 Flow Chart

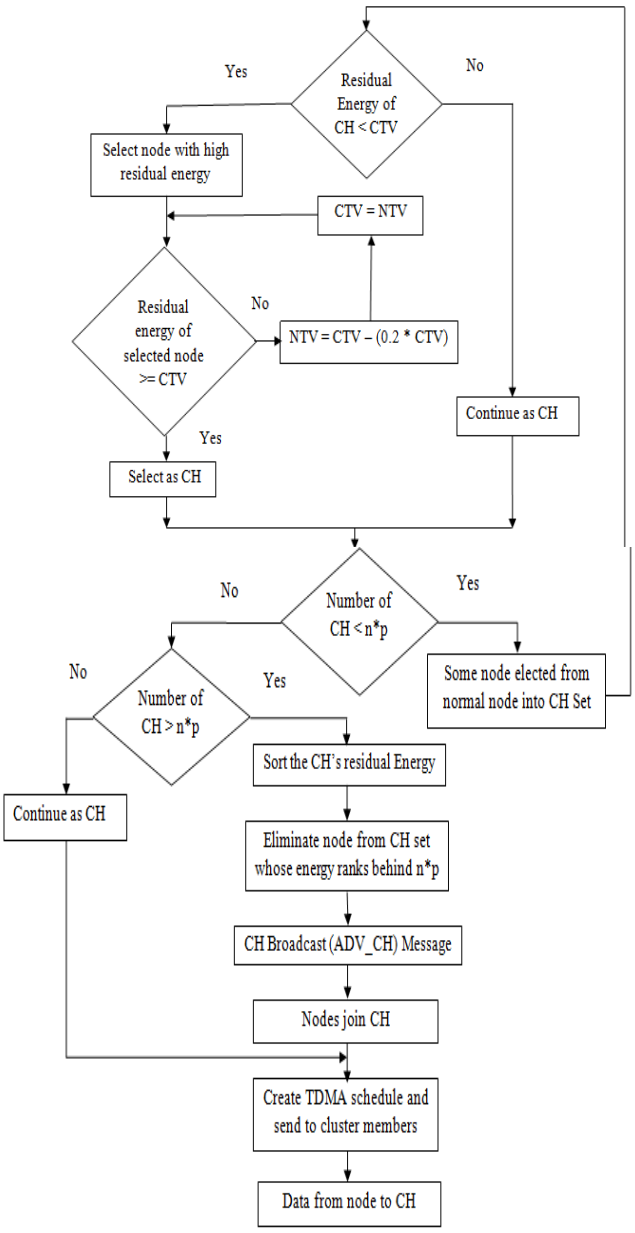

Figure 2: Flow chart of second selection of CH

4.3 Second Selection of the Cluster Heads

After completion of first round of data transmission, all nodes & CHs send their energy level to the base station. The base station selects cluster head whose energy level is above the threshold. Threshold = 100% of node energy (At first time of cluster formation) means 0.5J (if the initial energy of all nodes = 0.5J).

5% of the total numbers of nodes are assigned to be cluster head. LEACH-B [13] proves that system is the most energy efficient when there are between 3 and 5 clusters from the total 100 nodes in the network.

We should consider two different situations because of the energy consumption of cluster heads after completion of first round adopted by LEACH algorithm.

If the energy value of a cluster head is higher than threshold value, then there's not need to replace the cluster head. But if the energy value of cluster head below threshold than select new cluster head from the normal nodes whose residual energy above threshold. After completion of first round, CHs residual energy compare with threshold value. Due to energy consumption, neither all CHs nor normal nodes have 100% energy value. So, for that threshold value decremented by 20% from current threshold value. The threshold is set as:

$$NTV = CTV - (0.2 * CTV) \quad (1)$$

Where *NTV* = new threshold vale (e.g. *NTV* = 0.5), *CTV* = current threshold value.

After completion of second round, node whose energy value greater or equal to 80% means greater or equal to 0.4J (0.5 – 0.2 * 0.5) become Cluster Head.

In proposed approach, we perform another competition for cluster heads after selection of the cluster heads according to their residual energy to maintain the constant cluster head number of *n X p* Where *n* is the number of total nodes (e.g. *n* =100) and *p* is the desired percentage of cluster heads (e.g. *p* = 0.05) as per LEACH-B[13].

As per LEACH-B [13], we should consider two different situations because of the uncertain number of cluster head created by LEACH algorithm.

If the number of cluster head is less than *n X p*, some node with high residual energy should be elected from the normal node into the cluster head set and compare their residual energy with current threshold value (CTV). If node's residual energy is greater or equal to current threshold value (CTV) then select it as CH otherwise decrease the value of CTV and further compare node with CTV.
If the number of cluster head is greater than *n X p*, sort cluster heads according to their residual energy and eliminate node from cluster head set whose energy rank behind *n X p*, it is changed from CH to normal node.

5. Simulation and Result

To evaluate the performance of proposed method, we simulated both LEACH-B and proposed algorithm by Matlab.

To calculate the sending energy with using equation (2):

$$E(t) = (E_{elec} * k) + (E_{amp} * k * d * d) \quad (2)$$

5.1 Parameters for Simulation

Table 1: Simulation Parameters

Parameters	*Values*
Network Size	(0,0) to (100,100)
Number of Nodes	100
Base station location	(5,5)
Amount of data send by node each time(k)	4000 bits
Initial energy of nodes	0.5 J
Energy required in sending or receiving 1 bit(E_{elc})	50 nJ/bit
Data Aggregation Energy(EDA)	5 nJ/bit/signal
Energy consumed in amplifier(E_{amp})	100 pJ/bit/m^2

5.2 Figures and Analysis

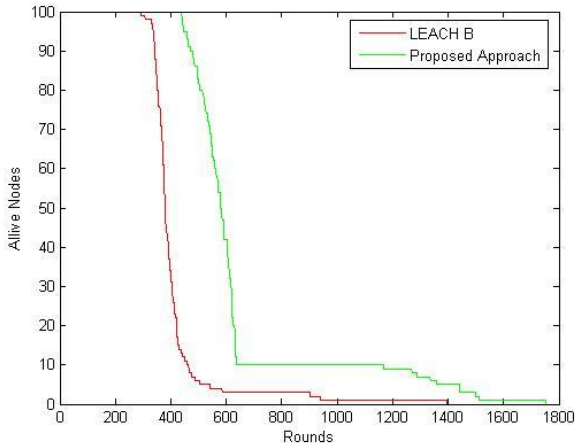

Figure 3: No. of Alive Nodes using LEACH-B and Proposed Approach

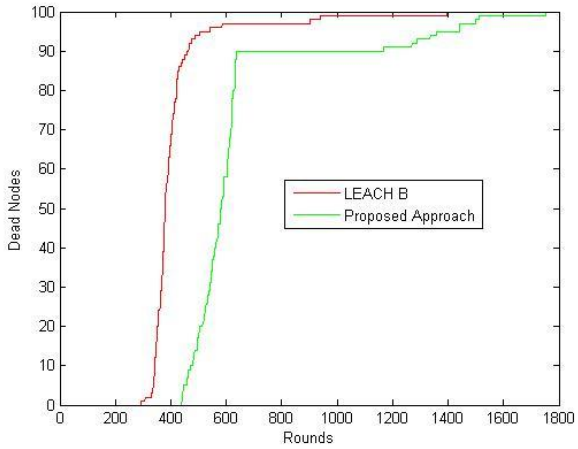

Figure 4: No. of Dead Nodes using LEACH-B and Proposed Approach

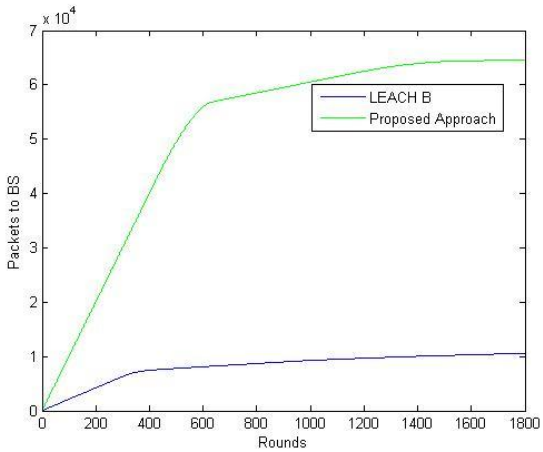

Figure 5: No. of Packets sends from CH to BS using LEACH-B and Proposed Approach

Figure 3 shows the Number of Alive Node using LEACH-B and proposed algorithm. Figure 4 shows the Number of Dead Node using the LEACH-B and proposed algorithm. Figure 5 shows the numbers of Packets send from cluster heads to base station.

As shown in the figure, all nodes in proposed algorithm die when it comes to 1700 rounds. While in LEACH-B, all nodes die when it comes 1400 rounds. Therefore, the lifetime of proposed algorithm has obvious larger than the LEACH-B protocol has increase life span of network effectively.

6. Conclusion and Future Work

Energy Efficiency for prolonging the WSN has received much focused attention. Battery unit determines the lifespan of the sensor network. Proposed Approach has good performance due to reduce cluster head selection and replacement cost and uniform distribution of cluster head. Our simulation result shows that Proposed Approach provides better energy efficiency and longer network life span than LEACH-B. We are considering mobility for further improvement. Security is vital and an important requirement. We can make the system more secure by putting more security features.

7. Acknowledgement

The authors wish to thank the Management, Principal, Head of the Department (Computer Engineering) and Guide of Sigma Institute of Engineering for the support and help in completing this work.

References

[1] K. Sohrabi et al., Protocols for self-organization of a wireless sensor network, *IEEE Personal Communications 7* (5) (2000) 16–27.

[2] R. Min, et al., Low power wireless sensor networks, in: Proceedings of *International Conference on VLSI Design*, Bangalore, India, and January 2001.

[3] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey" Elsevier Computer Networks 38 (2002)

[4] K. Chan, F. Fekri, and H. Pishro-Niki, Analysis of hierarchical algorithms for wireless sensor network routing protocols, *IEEE Wireless Communications and Networking Conference*, vol. 3, pp. 1830 1835, 2005.

[5] W. Heinzelman, A. Chandrakasan and H. Balakrishnan,"Energy-Efficient Communication Protocol for Wireless Micro sensor Networks," Proceedings of the *33rd Hawaii International Conference on System Sciences (HICSS '00),* January 2000.

[6] O. Younis, S. Fahmy, HEED: A Hybrid, Energy-Efficient, Distributed clustering approach for Ad Hoc sensor networks, IEEE Transactions on Mobile Computing 3 (4) (2004) 366–379.

[7] K. Xu, M. Gerla, A heterogeneous routing protocol based on a new stable clustering scheme, in: Proceeding of *IEEE Military Communications Conference (MILCOM 2002)*, Anaheim, CA, October 2002.

[8] S. Lindsey and C.S. Raghavendra "PEGASIS: Power-efficient gathering in sensor information systems". In *IEEE Aerospace Conference Proceedings*, 2002, Vol. 3. No. 9-16, pp. 1125 1130.

[9] Razieh Sheikhpour, Sam Jabbehdari " An energy efficient chain based routing protocol for wireless sensor networks" KSII Transactions on Internet and Information Systems Vol. 7, No. 6, Jun. – 2013
[10] Bhawnesh Kumar, Vinitkumar Sharma "Distance based Cluster Head Selection Algorithm for Wireless Sensor Network" International Journal of Computer Applications, Volume 57, November 2012.
[11] Y. Mao, L. Chengfa, C. Guihai, and J. Wu "EECS: An energy efficient clustering scheme in wireless sensor networks". In Proceedings of the 24th IEEE International Performance, Computing, and Communications Conference (IPCCC'05), Phoenix, Arizona, USA, Apr. 2005, pages 535–540.
[12] X. Co, H. Zhang, J. Shi, and G.Cui "Cluster heads election analysis for multi-hop wireless sensor networks based on weighted graph and particle swarm optimization". In ICNC '08 Proceedings of the 2012 Fourth International Conference on Natural Computation - Volume 07, pages 599–603.
[13] Tong, Minghao Tang "LEACH-B: An Improved LEACH Protocol For Wireless Sensor Network" College Of Information Science And Technology, Donghua University Shanghai, China, 2010 IEEE Page: 4.

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