Improved Network Connectivity using Energy Aware Threshold based Efficient Clustering (EATEC) Algorithm for Wireless Sensor Networks

K S Shivaprakasha
Centre of Excellence in Wireless Sensor Networks
Department of Electronics and Communication Engg
National Institute of Technology Karnataka
Surathkal 575 0125 (India)

Muralidhar Kulkarni
Centre of Excellence in Wireless Sensor Networks
Department of Electronics and Communication Engg
National Institute of Technology Karnataka
Surathkal 575 0125 (India)

ABSTRACT
Wireless Sensor Networks (WSNs) have become one of the most prominent areas of research in the field of modern communication systems. But unlike IP based routing, WSNs focus on data centric communication. Thus routing is one of the important issues to be considered for a wireless network. As sensor networks are generally deployed in hostile environments, batteries cannot be recharged often. Thus energy conservation is one of the important design parameters for WSNs. Many energy aware routing protocols were proposed in the literature. Cluster based algorithms were proved to be better compared to multi hop routing. In this paper an attempt has been made in proposing a novel cluster based energy efficient routing algorithm for WSNs, Energy Aware Threshold based Efficient Clustering (EATEC) algorithm, which incorporates a centralized process of Base Station (BS) selecting Cluster Heads (CH) based on its residual energy. The proposed algorithm proves to be better compared to LEACH.

General Terms
Wireless Sensor Networks, Clustering Algorithm

Keywords
Clustering, Cluster Head, LEACH protocol, Energy Aware Threshold based Efficient Clustering.

1. INTRODUCTION
A WSN is a network of sensor nodes deployed in a large geographical area. Nodes in a WSN are generally termed as motes and are deployed either randomly or uniformly. Motes sense some physical entity like temperature, pressure, humidity etc. The sensed information will be then conveyed to the central entity called the Base Station (BS) [1, 2, 3, 4].

Motes in the network consist of a sensor to sense the information, processor to process the sensed information, location finding system, transmitting and receiving units, memory and power units. Nodes are generally powered by batteries which cannot be recharged often. Thus data communication in WSN has to be accomplished using minimum energy. Unlike other networks, as WSNs do not have a fixed infrastructure, energy conservation is one of the real challenges for data transmission [5].

In most of the WSN applications, data is more important than the node having the data. Thus content based routing is generally used in WSN which is different from normal global address based routing being used in the Internet. As WSNs are densely deployed, nodes with close proximity are likely to have correlated data resulting in redundancy. Thus it is desirable to combine all data obtained from nodes within a common geographical area before sending it to the BS. The process of performing this is known as data aggregation. Generally the Cluster Head (CH) does the data aggregation within its cluster. As IP based routing relies on some fixed infrastructure during communication, energy conservation is not a critical issue. Whereas it is one of the important design parameters for routing protocols in WSNs. [8, 9, 10].

In literature many energy aware routing protocols were proposed. LEACH is proved to be an optimal energy aware protocol for WSNs. However it does not considers residual energy of the nodes into account. Thus LEACH can be further improved by incorporating a variable threshold set based upon the residual energies of the nodes. In this paper an attempt has been made in improvising LEACH by modifying the CH selection process to consider the residual energy along with the distance metric resulting in EATEC. The algorithm uses a centralized approach for CH selection. EATEC is simulated in NS2 and is proved to perform better than LEACH.

The rest of the paper is organized as follows: Section II gives an insight on the related works in the field of energy aware routing algorithms. Section III details LEACH protocol. Section IV gives an overview on the proposed protocol, EATEC. Section V gives the simulation results and analysis. Finally section VI gives concluding remarks.

2. PREVIOUS WORKS
A lot of protocols have been proposed in the literature. This section gives an insight on some of the important energy aware routing protocols developed for WSNs.

Geographical Adaptive Fidelity (GAF) is an energy conservative routing protocol proposed in [11]. GAF is independent of the underlying routing protocol. It conserves energy by identifying and turning off the unnecessary nodes in the network. A novel energy aware protocol, Geographic and Energy Aware Routing (GEAR) is proposed in [12] which selects its neighbor based on the energy parameter and geographical information.

Some of the applications of WSNs require critical time constraint. Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is one such protocol which assures time criticality [13]. Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is a cluster based energy aware routing algorithm proposed in [14]. In PEGASIS, each node

communicates only with its neighbor but not to the CH directly, which reduces the energy consumption at every node.

Energy Aware Random Asynchronous Wakeup (RAW-E) is an energy aware protocol proposed for heterogeneous networks [15]. RAW-E distributes the load among the nodes in the forwarding set proportionally to their remaining energy. Reliable Energy Aware Routing (REAR) is an on demand routing protocol which focuses on error avoidance than error correction. It assures reliable transmission with minimal energy consumption. Energy extinction is reduced by avoiding retransmission of the packets. REAR assures an energy sufficient path [16].

Minimum Energy Relay Routing (MERR) is an Energy Aware protocol proposed for WSN which takes into consideration the linear topology of the network [17]. It assumes that the sensor nodes transmit data to the BS via relay nodes and the distance between the relay nodes has to be approximately equal to the characteristic distance.

SeNsOr netWork CLUSTERing (SNOW) is a cluster based algorithm in which nodes with higher residual energy are chosen to be the CHs [18]. In [19] authors propose a hybrid protocol, Hybrid Energy Aware Routing Protocol (HEARP) which combines the features of both LEACH and PEGASIS. In HEARP members in the clusters will not communicate directly with the CHs but through the intermediate nodes.

Partitioning LEACH (PLEACH) is an improvement over LEACH proposed in [20]. PLEACH first does the optimal partitioning of the network and then the node with the highest energy in each partition will be chosen as the CH. It outperforms LEACH as the CHs are evenly distributed over the network. Distance based Energy Aware Routing (DEAR) optimizes the load balancing [21]. DEAR operates in two phases viz route setup and route maintenance. Source node initiates the route setup phase.

3. LEACH PROTOCOL

Clustering is a process of grouping sensor nodes based on its location. Cluster based routing is proved to perform better. Scalability can be easily achieved with nodes operating hierarchically. Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster based routing protocol for WSNs [22].

It is assumed that the BS is stationary and all nodes in the network are energy constrained. However BS is connected to fixed infrastructure and thus is less energy constrained. Cluster set up is based on the localized coordination and co operation. CHs are chosen on the rotation basis so that the load distribution amongst nodes is almost uniform.

Radio model is used as the energy model. In LEACH nodes organize themselves as clusters and one of the nodes is chosen as a CH. Initially each of the nodes has to decide whether to become the CH in the present round depending on some probability. Each node selects the cluster to which it has to belong depending on the energy required to reach the respective cluster head.

CH allocates the schedule to all nodes in the cluster, collects the data. It performs data fusion and then transmits to the BS.

CH will be changing periodically. Optimal percent of nodes being cluster heads is found to be around 5%. LEACH being dynamic clustering algorithm outperforms static clustering mechanisms. All CHs use different CDMA codes for communication so that there will not be any interference amongst the CHs.

4. EATEC PROTOCOL

The proposed Energy Aware Threshold based Efficient Clustering (EATEC) protocol differs by the variables on which the criteria of changing the CH depend on the residual energy of the nodes [23]. In LEACH the clustering and the process of CH selection totally depends on time. Whereas, in our proposed technique the change of CH depends on the energy variable. The CH is changed only when the current cluster looses down its energy below that of the threshold value.

4.1 Algorithm

Initialization: There are number of sensor nodes which are spatially distributed in a network as shown in figure 1. The information of locations of all nodes will be stored in the BS.

Initial process of clustering is done by the BS. The BS initiates the process by sending an energy request message to all the nodes to respond regarding the energy level. BS selects the CH depending on the residual energy of nodes and also on the basis of response time. Node with high energy gets a chance to become the CH. It is as depicted in figure 2.

Cluster Formation: The nodes having higher energies will be elected as CHs by the BS as shown in figure 3.

Nodes which get chance to become CH initially send a hello message to the nodes which are in its range. The neighboring nodes getting the hello message will respond to the message and become the members for the respective cluster. Similarly, the procedure is repeated until all clusters are formed.

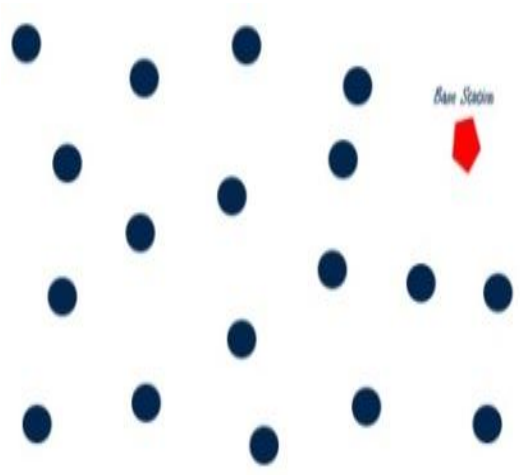

Fig 1: Sensor Node Deploy in the Region

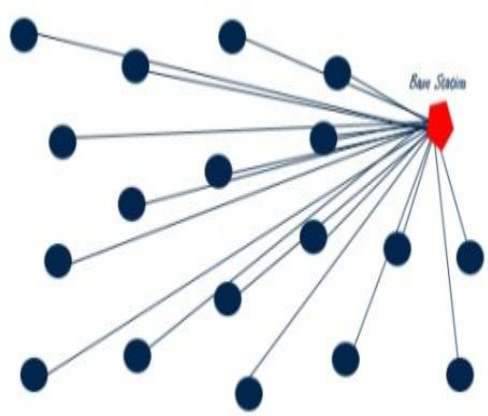

Fig 2: Sensor Nodes Sending their Energy to BS

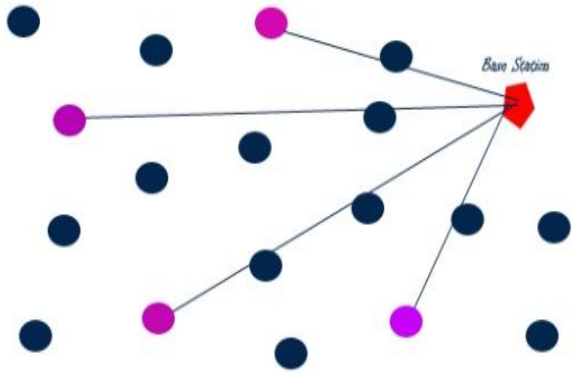

Fig 3: CHs are Selected by the BS

All the nodes which are in the range of a CH will receive a hello packet. If a node receives a hello packet more than once, it will discard all duplicate messages. Initial cluster formation is as depicted in figure 4.

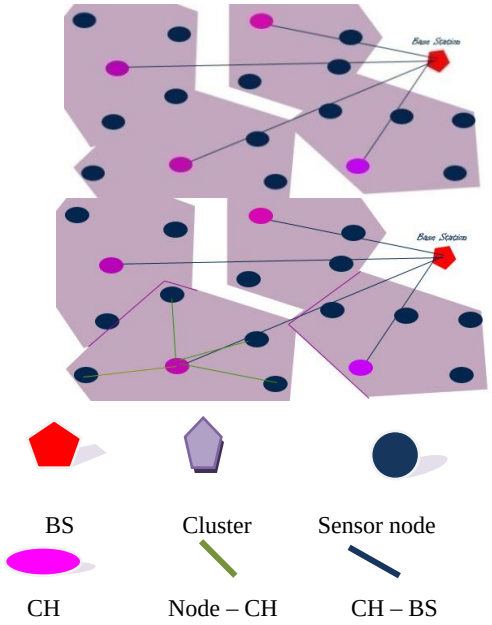

Fig 4: Concept of Initial Clustering Scheme

If a node remains unconnected to any of the formed clusters, then it will join one of the nearby clusters by advertising its existence.

Cluster Reformation: The process of cluster reformation or changing the CH will occur only when the CH's energy is reduced below that of the threshold energy value. The threshold value is manually changed.

The steps of changing the CH are mentioned below

1. The process is initiated when the energy of the CH is less than that of the threshold value.
2. As soon as the energy of the CH goes down the threshold, the information is conveyed to the BS.
3. The BS initiates the process of reformation of the clusters.
4. BS having location information of all nodes, performs the selection of the new CHs with minimal changes in the existing ones.

Routing and Data Aggregation: The process of routing and data aggregation is same as that of the LEACH protocol. The new CH will attempt to get a path to reach the BS.

Routing may be of single-hop or multi-hop as per the distance between the CH and BS. The route path between two nodes or BS will be stored in the routing tables of all the nodes.

5. SIMULATION AND RESULTS

Network Simulator (NS) version 2.34 is used as a simulation platform [24]. Simulations for both LEACH and EATEC were done by keeping the number of nodes, clusters and simulation time constant. 10 trials were considered and the mean of all the trials is taken to fetch the required results [25]. The simulation parameters are as shown in table 1.

Table 1. Summary of the Parameters

Parameters	**Value**
Simulation Time	3600 sec
Topology size	200 X 200 m^2
Number of nodes	100
Number of clusters	9
Number of trials	10
Initial node Energy	20 Joule
Nodes distribution	Randomly distributed
BS position	Located at (50, 120)

The following performance parameters were considered for the analysis:

Throughput: It is the amount of data delivered per unit time from the source to destination over a communication link. The throughput is measured in bits/sec.
Packet Transmission Ratio: It is the ratio of number of packets transmitted to the number of packets dropped.
Delay: The transmission delay encountered for the data transmission from sender to destination.
Energy Drain: Amount of energy drained in a node in the process of data transmission.
Data Transmission: The total number of data packets transmitted by a node before network rediscovery.

A comparison on the performance of the proposed EATEC with the traditional LEACH protocol is made. Figure 5 gives a plot of total energy consumption in the network for the process of data transmission. Energy drain in EATEC is less than that of

LEACH as EATEC considers residual energy of the nodes as a primary parameter in the CH selection process. It is inferred in the figure.

Figure 6 gives a comparison of the total number of packets transmitted before reformation of the clusters in both LEACH and EATEC algorithms. More number of packets is transmitted in EATEC as it offers less energy consumption per packet.

Nodes die due to battery extinction increases with simulation time. Nodes having sufficient energy to take part in routing process are termed as alive nodes. A plot of number of alive nodes as a function of simulation time is depicted in figure 7. As EATEC prolongs the network lifetime by choosing the CHs on energy parameter, the nodes dying due to battery extinction is lesser. It is clear from the plot that EATEC outperforms LEACH.

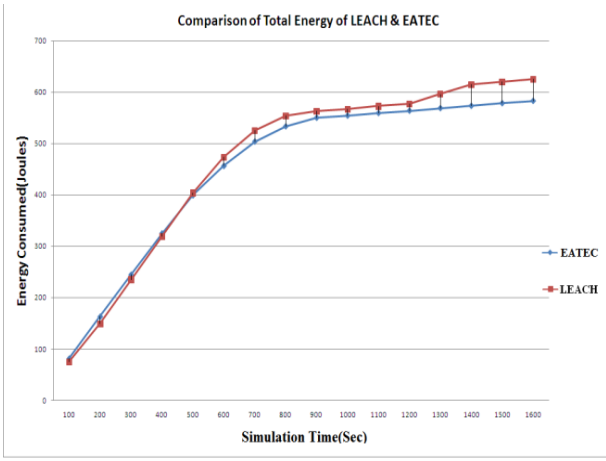

Fig 5: Comparison of Total Energy Utilized by LEACH and EATEC

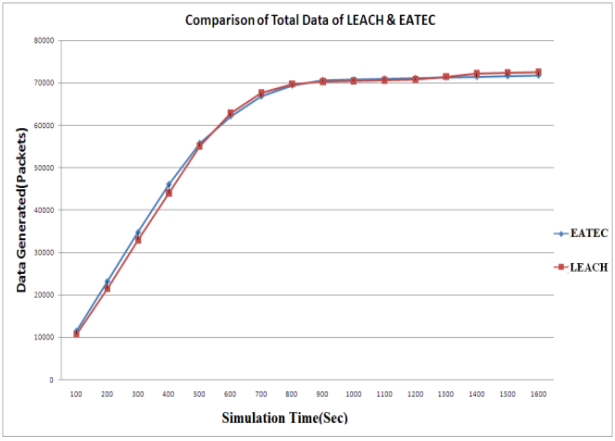

Fig 6: Comparison of Total Number of Data Packets Transmitted by LEACH and EATEC

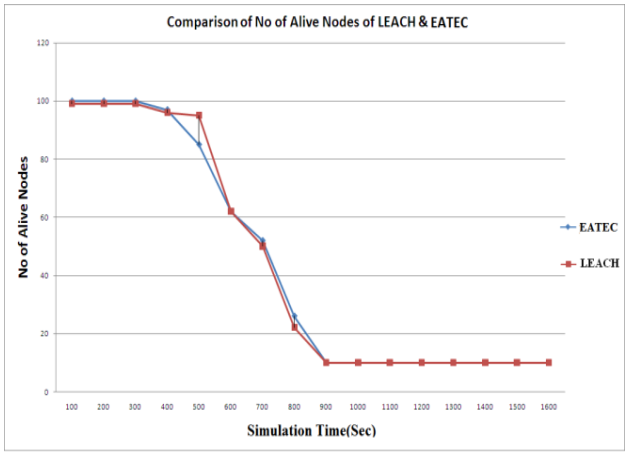

Fig 7: Comparison of Number of Alive Nodes in LEACH and EATEC

To find the total energy used in the network for data communication, 10 trails were taken for both EATEC and LEACH considering common network parameters and the average of the same is taken. Tables 2 and 3 detail the energy consumption per packet in LEACH and EATEC respectively for 10 trails.

It is clear from the tables that the average energy consumed in LAECH is found to be 21.18 mJ/pkt whereas that for EATEC is 14.37 mJ/pkt. Thus it has been seen from the simulation that the energy consumed by EATEC is 32.15% less as compared to LEACH protocol.

Table 2. Energy Consumption per Packet in LEACH

Trail No	Energy per Packet (in mJ/pkt)	Avg Energy per packet (in mJ/pkt)
1	10.47	21.18
2	25.64	
3	10.31	
4	10.30	
5	10.39	
6	10.16	
7	33.75	
8	9.85	
9	65.35	
10	25.63	

Table 3. Energy Consumption per Packet in EATEC

Trail No	Energy per Packet (in mJ/pkt)	Avg Energy per packet (in mJ/pkt)
1	9.06	14.37
2	11.75	
3	9.05	
4	9.05	
5	14.96	
6	9.07	
7	50.87	
8	11.78	
9	9.05	
10	9.07	

6. CONCLUSION

The process of clustering plays a very important role in achieving energy efficiency in a WSN. In this paper, an attempt has been made to change the criteria and process of clustering and CH rotation. EATEC, an improvement over LEACH has been proposed by incorporating centralized approach of BS performing cluster formation and CH selection based on the energy parameter. The CHs will be reformed by the BS if any of the CHs' energy goes below the preset threshold. The simulations were carried out in NS 2.34. It is observed from the simulation results that EATEC achieve 32.15% better energy efficiency than LEACH protocol.

7. REFERENCES

[1] David Culler, Deborah Estrin, Mani Srivastava. 2004. Overview of Sensor Networks. IEEE Computer Society. 41-49. August 2004.

[2] M.K.Jeya Kumar. 2010. Evaluation of Energy-Aware QoS Routing Protocol for Ad Hoc Wireless Sensor Networks, International Journal of Electrical, Computer, and Systems Engineering. Vol 4. No 3.

[1] Curt Schurgers, Mani B. Srivastava. Energy Efficient Routing in Wireless Sensor Networks. Military Communications Conference. MILCOM 2001. IEEE. Vol. 1. 357-361.

[3] Sinem Coleri Ergen and Pravin Varaiya. 2005. On Multi-Hop Routing for Energy Efficiency. IEEE Communications Letters. Vol. 9. No. 10. 880-881.

[4] C Siva Ram Murthy and B S Manoj. 2004. Adhoc Wireless Networks-Architectures and Protocols. Pearson education.

[5] Andrew S Tanenbaum. 2003. Computer Networks. 4e. Pearson Education.

[6] Behrouz A Fouruuzan. 2004. Data Communications and Networking. 3e. McGrawHill Publication.

[7] Rajashree.V.Biradar, V.C .Patil, S. R. Sawant, R. R. Mudholkar. Classification and Comparison of Routing Protocols in Wireless Sensor Networks. Special Issue on Ubiquitous Computing Security Systems. UbiCC Journal – Vol 4. 704-711.

[8] A. K. Dwivedi, Sunita Kushwaha, O. P. Vyas. 2009. Performance of Routing Protocols for Mobile Adhoc and Wireless Sensor Networks: A Comparative Study. International Journal of Recent Trends in Engineering. ACEEE. Vol 2. No. 4. 101-105.

[9] Kemal Akkaya , Mohamed Younis. 2005. A Survey on Routing Protocols for Wireless Sensor Networks. Elsevier. Ad Hoc Networks. Vol 3. 325–349.

[10] Chiara Buratti, Andrea Conti, Davide Dardari and Roberto Verdone. 2009. An Overview on Wireless Sensor Networks Technology and Evolution. Sensors. Vol 9. 6869-6896.

[11] Y. Xu, J. Heidemannn, and D. Estrin. 2001. Geography-Informed Energy Conservation for Ad Hoc Routing. Proc. of the Seventh Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom 2001). Rome. Italy. 70-84.

[12] Yan Yu, Ramesh Govindan, Deborah Estrin. 2001. Geographical and Energy Aware Routing: A Recursive Data Dissemination Protocol for Wireless Sensor Networks. UCLA Computer Science Department Technical Report UCLA/CSD-TR-01-0023.

[13] A. Manjeshwar, D.P. Agrawal. 2001. TEEN: a Protocol for Enhanced Efficiency in Wireless Sensor Networks. Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing. San Francisco. CA. IEEE April 2001.

[14] Lindsey, C. Raghavendra. 2002. PEGASIS: Power-Efficient Gathering in Sensor Information Systems. IEEE Aerospace Conference Proceedings. Vol. 3. 1125-1130.

[15] Vamsi Paruchuri, Arjan Durresi, Leonard Barolli. 2005. Energy Aware Routing Protocol for HeterogeneousWireless Sensor Networks. Proceedings of the 16th International Workshop on Database and Expert Systems Applications (DEXA'05). IEEE Computer Society. 133-137.

[16] Hossam Hassanein And Jing Luo. 2006. Reliable Energy Aware Routing in Wireless Sensor Networks. Proceedings of the Second IEEE Workshop on Dependability and Security in Sensor Networks and Systems (DSSNS'06). IEEE Computer Society. 54-64.

[17] Marco Zimmerling, Waltenegus Dargie and Johnathan M. Reason.2007. Energy-Efficient Routing in Linear Wireless Sensor Networks. IEEE International Conference on Mobile Adhoc and Sensor Systems. 1-3.

[18] Siho Cha, Minho Jo, Jong-Eon Lee, Dae-Young Kim, Seokjoong Kang, Kuk-Hyun Cho and Nobok Lee. 2007. Hierarchical Node Clustering Approach for Energy Savings in WSNs. IEEE Computer Society. 253-259.

[19] Azeddine Bilami, Djallel Eddine Boubiche. 2008. A Hybrid Energy Aware Routing Algorithm for Wireless Sensor Networks. International Symposium on Computers and Communications. IEEE. 975-980.

[20] Haosong Gou and Younghwan Yoo. 2010. An Energy Balancing LEACH Algorithm for Wireless Sensor Networks. Seventh International Conference on Information Technology. IEEE Computer Society. 822-827.

[21] Wang Jin, Imanishimwe Jean de Dieu, Asturias De Leon Diego Jose, Sungyoung Lee and Young-Koo Lee. 2010. Prolonging the Lifetime of Wireless Sensor Networks via Hotspot Analysis. IEEE Computer Society. 383-386.

[22] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan. 2000. Energy-Efficient Communication Protocol for Wireless Microsensor Networks. Proceedings of the 33rd Hawaii International Conference on System Sciences. IEEE.

[23] Brunda, J. S., B. S. Manjunath, B. R. Savitha, P. Ullas, K S Shivaprakasha. 2012. Energy Aware Threshold based Efficient Clustering (EATEC) for Wireless Sensor Networks. International Journal of Electronics Circuits and Systems.

[24] NS-2: Network Simulator (Retrived on 02/02/2012 from http://www.isi.edu/nsnam/ns/)

[25] LEACH Patch for NS2 (Retrived on 08/03/2012 from file://root/ns-allinone-2.34/notes/randomearly-detection-leach-in-ns-2-cl.html#uds- searchresults)