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A Cluster Head Election Method for Equal Cluster Size in Wireless Sensor Network

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1. Introduction

Wireless sensor networks (WSNs) are composed of many homogeneous or heterogeneous sensor nodes with limited resources. A sensor node is comprised of three components: a sensor, a processor and a wireless communication device. A sensor of nodes detect a change in surroundings, a processor processes sensing data collected from neighbour nodes or own environmental information, and a wireless communication device is capable to send and receive sensing data.

Sensor networks consist of a great number of sensor nodes and one or several sink nodes. The role of a sensor node is to detect and process own environmental information, to convert it to sensing data, to send it to neighbour nodes or sink nodes, and to collect it from neighbour nodes. On the other hands, the role of a sink node is to collect sensing data from sensor nodes and to be gateway that interconnects different network and transmits data to it.

Generally, sensor nodes of WSNs are randomly scattered on specific area for satisfying user's requirements (detecting, observing and monitoring environment) and have to self-organized network. It is difficult to exchange and charge node battery as the area where sensor nodes are located in is inaccessible location. So, it is important issue to design power-efficient protocol method for low-power operation and prolonging the network lifetime (Akyildiz et al, 2002).

A sensor node needs wireless ad-hoc network capability to collect sensing data of wireless sensor network without a communication infrastructure. Sensor networks are, however, not suitable for the existing ad-hoc routing method (Tubaishat & Madria, 2003) because of sensor nodes with limited capability. Thus sensor networks require wireless ad-hoc routing method considering self-organization, restrictive power, and data-based communication(Sohrabi et al, 2000) and need multi-hop routing mechanism because of the limited transmission radius of a sensor nodes.

WSNs should design for routing algorithm considering low-power operation because it has limited features and is a traditional wireless networks completely different from 'the network(Al-Karaki & A.E. Kamal, 2004). In WSNs, routing methods can divide into two routing mechanisms: 'flat-routing' and 'hierarchical-routing'. The 'flat-routing' technique regards the whole network as one region, enabling all nodes to participate in one region. On

the other hands, the 'hierarchical-routing' technique is to execute local cluster routing scheme based on clustering.

The feature of sensing data is that adjacent sensor nodes have similar or same sensing data(Ameer Ahmed Abbasi and Mohamed Younis, 2007). That is, the duplicate sensing data exist in sensor networks. To prevent duplicate sensing data, the 'hierarchical-routing' technique uses the clustering scheme. The Cluster region is a local area assigned by user's requirement. It is composed of a cluster head node and member nodes. A cluster head is for aggregating sensing data from member nodes. The number of sensing data in the 'hierarchical-routing' is lower as cluster head works. Thus, the 'hierarchical-routing' is more energy-efficient routing technique than the 'flat-routing'.

A process of clustering is as follows. First, a sink node elects cluster heads among all scattered sensor nodes. Each cluster head makes a local cluster by using advertisement message. Member nodes send sensing data to own cluster head. A cluster head collects sensing data from member nodes for 'data-aggregation' that prevents duplicate data. When a sink node requests user-demand, in response to user-demand, a cluster head prevents unnecessary query flooding. To communicate with sensor nodes which are outside sensing range, a sensor node is suitable for multi-hop networking(Toumpis & Goldsmith, 2003). It is important to measure the number of cluster member nodes in local cluster based on multi-hop clustering. If there are many member nodes in local cluster, the energy consumption in a local cluster is increased. The energy drain of a cluster head is also increased. On the other hand, if there are little member nodes in a local cluster, the energy consumption is low. The energy drain of a cluster head is also low. Thus, it is important how many member nodes are needed to set up a local cluster for energy-efficient sensor networks.

This chapter shows energy-efficient cluster formation method. To achieve this, a local cluster should know the number of optimal member nodes and adjusts the position of a cluster head considering the distance between cluster heads and member nodes. That is to build balance among local clusters. Thus, this method can find low-power mechanism of sensor networks for clustering.

The organization of this chapter is as followings: in section 2, we shows an overview of previous clustering methods and describe problems of them. In section 3, we present the cluster head election method for equal size. In section 4, we compare previous methods with the proposed method, and analyze them. Finally, in section 5, we present conclusion and future works.

2. Clustering mechanism for sensor networks

2.1 Cluster head selection with random costs

The typical clustering method is LEACH(Heinzelman et al, 2000). LEACH is a routing method based on clustering for distribution energy consumption of wireless sensor networks. The feature of LEACH is a clustering method to distribute energy consumption to all sensor nodes in sensor networks. To achieve this, LEACH elects randomly a cluster head which aggregates sensing data from member nodes in local cluster and processes them for managing a local cluster workload. LEACH consists of two stages: 'set-up' stage and 'steady-state'. The 'set-up' stage is to form a cluster and the 'steady-state' stage is to comprise of several TDMA frames. In 'set-up' stage, all sensor nodes select a cluster head by threshold T(n) in equation 1. Each node selects random number between 0(zero) and 1(one).

If the selected number is a smaller number than threshold T(n), the node that has a smaller number is a cluster head in the current round.

$$T(i) = \begin{cases} \dfrac{p}{1 - p * (r \bmod \dfrac{1}{p})}, & i \in G \\ 0 & ,otherwise \end{cases}$$
(1)

In equation (1), p is the ration of a cluster head, r is the current round, and G is a set of nodes that were not a cluster head in 1/p round. By equation (1), all nodes only become a cluster head among 1/p round once. The more round is increased, the more probability which a node becomes a cluster head is increased. After 1/p round, a node can become a cluster head with same probability, again. The energy drain of cluster head is so bigger than a member node because of aggregating, processing and sending sensing data from member nodes. To prolong sensor network lifetime, a cluster head have to be circulated. Through this mechanism, LEACH can circulate equally a cluster head. A fair distribution of cluster head selection might make equal energy consumption of cluster heads and be probable for fair energy consumption of all sensor nodes in sensor networks.
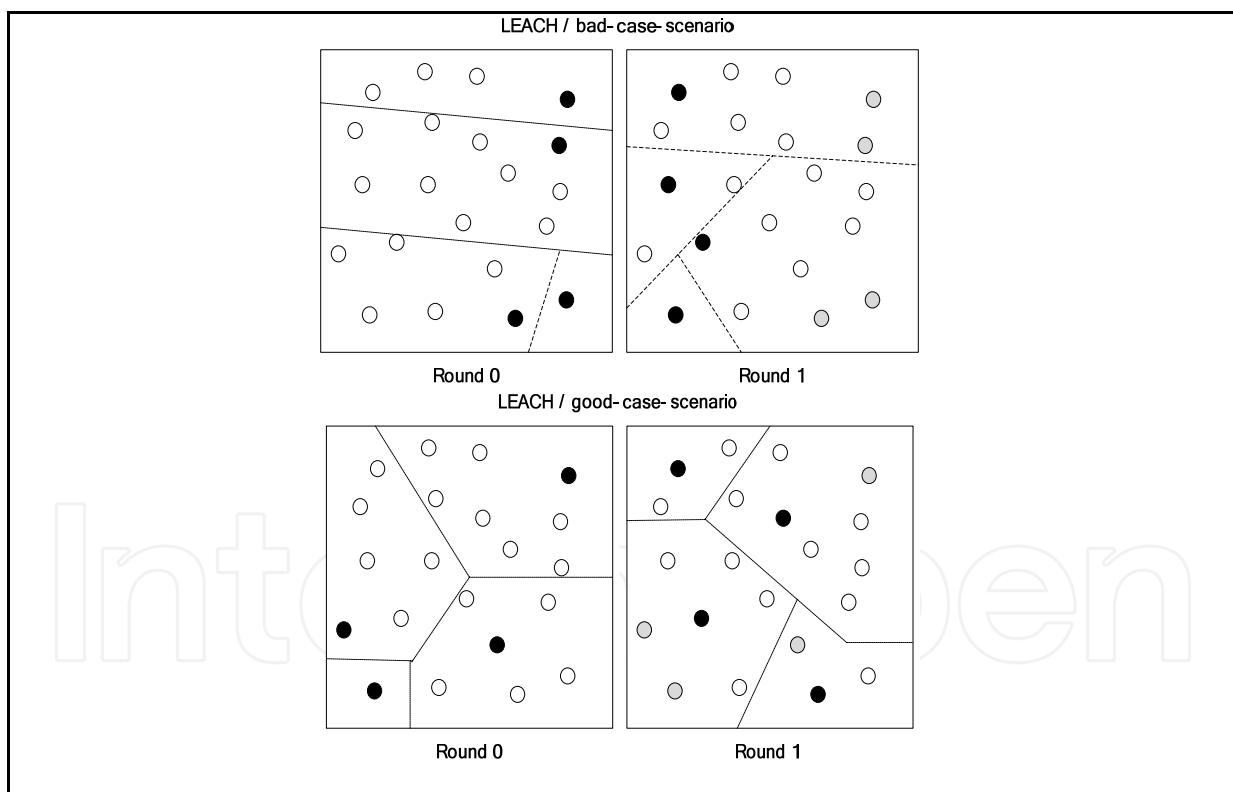

Fig. 1. Cluster formation in LEACH

When LEACH organizes a cluster, it can form equally a cluster (good-case-scenario) or not (bad-case-scenario). In LEACH, as a local cluster is organized by the selected cluster head, location of cluster heads affects the number of member nodes in a local cluster. If there are many member nodes in local cluster, the energy spending of a cluster head is increased. On the other hand, if there are little member nodes in local cluster, the energy consumption of a

cluster head is decreased. That is, that the energy consumption of cluster head is affected by the number of member nodes. As a result, in LEACH, it is difficult to keep up the balance of node energy of whole sensor networks.

In LEACH, all member nodes delivery sensing data directly to a cluster head or the sink node because LEACH assumes transmit power control. However, a sensor node is suitable for communicating the node with outside sensing range based on multi-hop routing method because of node's communication limited(Gutierrez et al, 2001, Noseong Park et al, 2005). That is, in case of outside the range of a cluster head or the sink node, sensor networks should organize clustering using multi-hop routing mechanism.

LEACH-C(LEACH-Centralized)(Heinzelman et al, 2002) is similar to LEACH. That means that two algorithms are same to data transmission processes between the BS and the sensor nodes. On the other hand, the process of cluster head selection in LEACH-C is different with LEACH. LEACH-C uses a central control algorithm to form the clusters that may produce better clusters by dispersing the cluster head nodes throughout the network. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using a GPS receiver) and energy level to a sink node. A sink computes the average energy level of all nodes by received message, and then give the right which is not possible for the cluster heads if the sensor node have lower energy than the average energy level. Using the remaining nodes as possible cluster heads, the BS finds clusters using the simulated annealing algorithm(Murata & Ishibuchi, 1994) to solve the NP-hard problem of finding optimal clusters(Agarwal & Procopiuc, 1999). This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster head, by minimizing the total sum of squared distance between all the non-cluster head nodes and the closest cluster head. After the cluster heads are elected, member nodesf can select the cluster head which they can communicate with minimum energy consumption. A cluster is organized by the node transmitting the message as a determined cluster head node. After clustering, The cluster heads perform TDMA scheduling, transmit the schedule to member nodes in local clusters, and then start the data transmission time. The strong point of LEACH-C is that it can equally distribute waste to energy between sensor nodes by positioning cluster heads into the center of cluster. A sensor node, however, should be loaded with GPS receiver set. And it has not still guaranteed balance of energy consumption of whole sensor networks. This technique makes the price of sensor nodes increase high. Because of a number of sensor nodes to be needed for the network ranges from hundreds to hundred-thousands, this technique is not appropriate(Handy et al, 2005).

Above two methods increase the energy consumption because of additional overhead for knowing the energy level. To achieve this problem, HEED(Younis & Fahm, 2004) proposes the cluster head selection method using by distributed processing. HEED can select the cluster heads only considering the parameters of nodes. In HEED, the cluster head election should use only local data, have low amount of data for clustering and be completed in a certain period of time. Thus the advantages of HEED are that algorithm time terminate in a certain period of time regardless of cluster size and do not consider the location of nodes. HEED do not also guarantee the equal distribution of the cluster heads in networks like LEACH and LEACH-C.

2.2 Cluster head selection with equal member nodes

ACHS(Adaptive Cluster Head Selection)(Choon-Sung Nam, 2008) is the method to divide unequal cluster size into equal cluster size for balance of energy consumption in a local cluster. In case the number of member nodes per a local cluster is more or less than average number of member nodes, this cluster could be an unequal cluster. To solve unfairness among local clusters, ACHS re-selects cluster heads using by distance between cluster heads and between member nodes and a cluster head. This method is as follows. First, the sink node elects a cluster head randomly like LEACH equation (1). The selected cluster head informs neighbor nodes for an advertisement message. In response to the message, each member node registers with own cluster head. A cluster head sets up and stores the farthest member node (FMN) with cache memory among member nodes. In the same way, it keeps the shortest cluster head (SCH) with cache. If the difference of FMN and SCH is same, this means that local clusters are divided into equal cluster size.

In Fig. 2-(a), if the gap of FMN is longer than SCH, in case of cluster head 'A', the cluster size is bigger than neighboring cluster size as the cluster which has cluster head 'A' invades a domain of neighboring cluster which has cluster head 'B'. In other words, that cluster size is bigger means that the number of member nodes is so more. Thus the cluster head 'A' should be moved to FMN as difference between FMN and SCN, and is reselected a cluster head among near nodes. If the gap of FMN is shorter than SCH, in case of cluster head 'B', the neighboring cluster size is bigger than the cluster size of 'B' as the neighboring cluster 'A' invades own domain. Thus, the cluster head 'B' moves to SCH as difference between FMN and SCH, and is reselected a cluster head among near nodes. After these processes, a local cluster would be divided equally like Fig.2-(b).

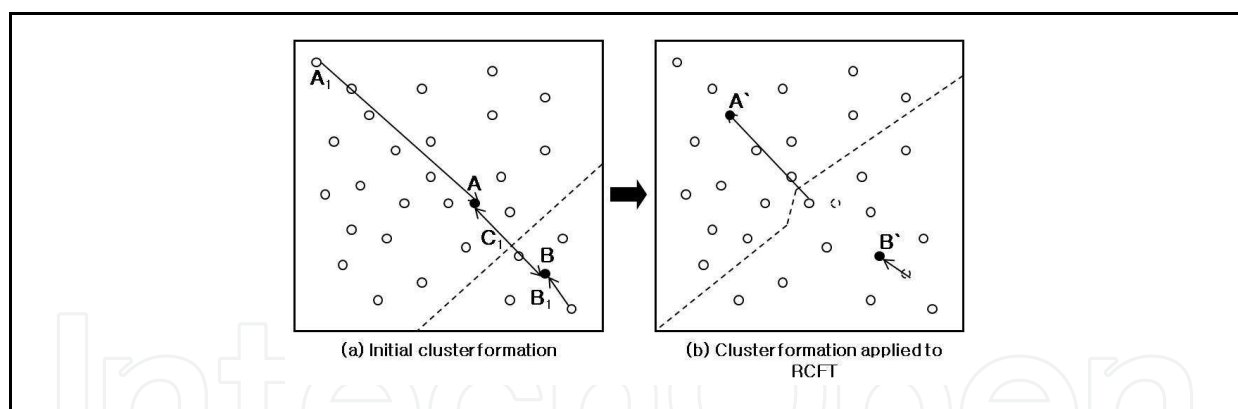(a) Initial cluster formation   (b) Cluster formation applied to RCFT

Fig. 2. Cluster organization using by adaptive cluster head selection method (ACHS)

ACHS used direct data transmission method that computed the distance between cluster heads and member nodes. ACHS has the same problem on communication range like LEACH. In case of outside transmission range, it cannot communicate with outside nodes. As a result, it is difficult to establish scalable network. Thus ACHS also need to multi-hop routing method for clustering. Another problem has to be to reorganizes the equal cluster unnecessarily for equal clusters although previous established local cluster is equal.

3. Cluster Head Election Method for Equal Cluster Size

3.1 Cluster head capacity

This method is for energy distribution as all sensor nodes would be selected as a cluster head after 1/p round. And it helps efficient-energy saving of nodes since the nodes which has high remaining energy are elected as a cluster head. However, it does not consider unequal energy consumption of nodes by unequal clusters. The elected cluster head is not again selected as a cluster head during 1/p rounds although the node has the most energy than others.

Above described, we knew that the energy gap between a cluster head and a member node is big during managing clustering. This reason is as following: A member nodes just detects own surrounding environment and transmit the sensing data to a cluster head. A mount of aggregated data produced by a cluster head depends on the number of own member nodes. Thus a cluster head should be selected by energy drain ratio as setting up threshold, T(i).

As shown equation (2), if r is 0, r=0, the probability of all sensor nodes, T(i)r=0, is 'p' because all sensor nodes have not been selected as a cluster head.

$$T_{i=0}(i) = \begin{cases} \dfrac{p}{1 - p * (r \bmod \frac{1}{p})} = p, i \in G \end{cases} \tag{2}$$

If r >0, the threshold value of a node that is selected as a cluster head is reduced by amount of energy consumption. The consumption energy ratio, $E_{ch}/E_{initial}$, added to the previous threshold value is the next threshold value. E_{ch} is amount of energy drain of a cluster head and $E_{Initial}$ is initial energy of nodes. If a node is a member node, the consumption energy ratio, E_{mem}/E_{inital}, subtracted from the previous threshold is the next threshold value. This is as following:

$$T_{i=0}(i) = \begin{cases} T(i)_{r-1} - \dfrac{E_{mem}}{E_{Initial}}, i \in G_{r-1} \\ T(i)_{r-1} - \dfrac{E_{ch}}{E_{Initial}}, otherwise \end{cases} \tag{3}$$

Except for the case that E_{ch} is same as E_{mem}, all nodes are selected as a cluster head at least once during 1/p rounds. In next rounds of cluster head selection, the nodes' threshold value that is used with cluster head selection is different as is a cluster head energy consumption in own local cluster. This difference is from the fact that the number of member nodes in local cluster varies from each other. If a cluster head has fewer member nodes than the average number of member nodes, the threshold value is also lower. This means that the cluster head is re-selected as a cluster head during 1/p rounds. This will result in energy distribution of sensor networks and increasing network life time.

3.2 Equal cluster size

In direct communication, if sensor nodes are located out of transmission range, cluster heads should be more selected for connecting nodes. To configure the scalable sensor networks,

the clustering method should use multi-hop communication. For cluster formation adapted multi-hop routing, a local cluster should be organized by the selected cluster head. First, a sink node selects a cluster head, 5% nodes among all nodes, like LEACH. The selected cluster head sends the ADV message to neighbour nodes with 1(one) hop for collecting member nodes. Nodes which received the message repeat this process until they meet the nodes of another local cluster. The nodes which received the ADV message judge what kind of a cluster head. The nodes set up a cluster head as the cluster head id (CHid) included the ADV message, increase their hop-count by one and reply the REP message to own cluster head. And then a cluster head registers own sensor id. Through this process, a cluster head can know the number of own member nodes and hop counts between own and member nodes(Choonsung Nam, 2008)

The pseudo code of clustering process based on multi-hop is as follows.

Procedure cluster formation	
Input	selected cluster head id
Output	node Information belonging to cluster
If received ADV from cluster head Then	
Begin	
If (Node.My_CHid != null)	
insert into Node_Info_values(CHid, Hopcnt++)	
reply REP to sender	
send ADV message to neighbor nodes	
return true	
Else	
return false	
End	
ADV	Advertisement message
REP	Respond message
CHid	Cluster head id
Hopcnt	Hop count
Node_Info_value	Node information value

Fig. 3. Pseudo code for clustering process based on multi-hop

To prevent unequal cluster formation, above method only proposed equal cluster formation technique using difference between the FMN and the SCH. To balance the clusters, we add above method to the method which is to balance the number of member nodes. For example, in Figure 20, 200 sensor nodes are located in 10 x 10 grid structure. The cluster head is gray circle A, B, C, D and E, 5% among 100 sensor nodes. By multi-hop clustering method based on the CH, a cluster can be organized local cluster like a dotted line. The alphabet 'A', 'B', 'C', 'D' and 'E' are the CHs. The number of member nodes each CH has is that A is 21, B is 16, C is 14, D is 21, and E is 23. Above mentioned, a cluster head can know the number of own member nodes and the adaptive number of member nodes. In this example, the adaptive number of member nodes is 19, (all sensor nodes / cluster heads). So, cluster head 'A' and 'D' is adaptive cluster distribution. The cluster head 'B', 'C' and 'E' is not adaptive. To balance the clusters, the clsuter heads are replaced with the dark circle 'A', 'D', and 'E'. Cluster head 'B' and 'E' is not replaced because the hop count of FMN and SCH

is same. The change of cluster area is black line. The number of cluster member nodes (black line) is that A is 21, B is 18, C is 10, D is 22, and E is 24. That is unequal cluster division than previous cluster formation. Cluster 'E' is changed more unequal cluster size. Specially, cluster 'C' is more unequal cluster size than before. The cases of imbalance cluster are as following:
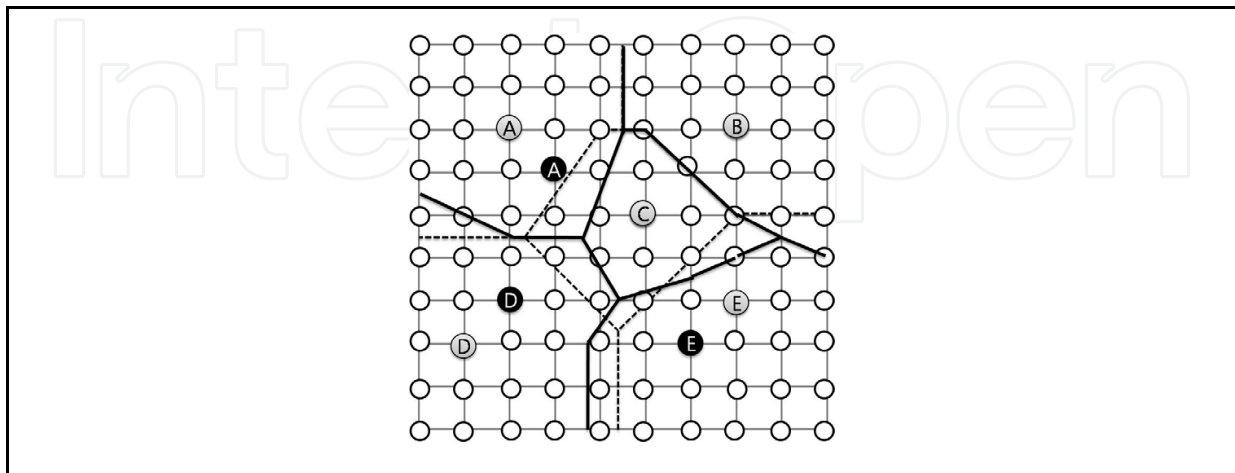

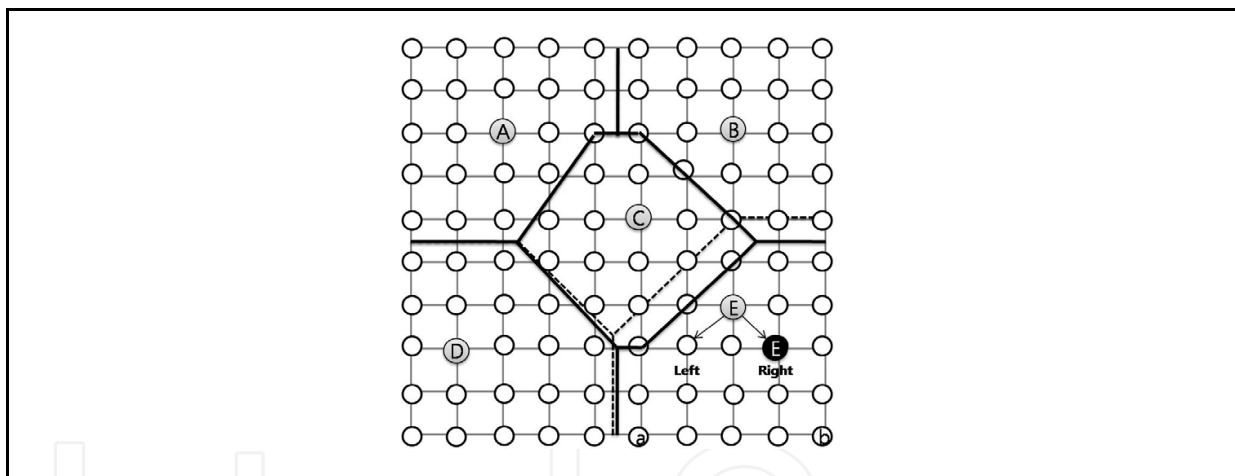Fig. 4. Imbalance of a local cluster by changing cluster heads

Fig. 5. Balance of a local cluster by keeping the adaptive clusters

Although a local cluster has adaptive number of member nodes(all nodes/th number of cluster heads), the replacement of cluster head is elected to only balance the size of local cluster. This method do not guarantee adaptive local cluster as the previous adaptive local clusters are changed. If local clusters are imbalance, the replacement of cluster head should be selected by the current cluster head for balancing clusters. The previous method does not have the condition which node is better as a cluster head with same distance or hop counts. To achieve this problem, we don't change the adaptive cluster and change only unequal cluster. We define the adaptive cluster that has the number of member nodes with plus or minus 10% of the adaptive number of member nodes. That is from 17 to 21. In Fig.5, the equal local cluster is 'A' and 'D'. The unequal local cluster is 'B', 'C' and 'E'. The proposed method changes them. Cluster 'B' and 'C' have same distance between the FMN and the

SCH and they don't re-select their cluster head. According this method, cluster 'E' is only replaced. The SCH of cluster 'E' is the cluster 'C' and the hop count of it is 2. The FMN of cluster 'E' is node 'a' or 'b', and hop count of it is 3. Cluster head 'E' should move to the FMN ('a' or 'b') as 1 hop as the difference between the FMN ('a' or 'b') and the SCH ('C') is 1. At this time, the cluster head 'E' should decide node 'a' or 'b' as the FMN. The 'E' selects node 'b' as the FMN because node 'b' is farther than 'a' from the SCH 'E'. The farther difference between 'C' and 'E', the more member nodes 'C' gets. The number of cluster member nodes by the proposed method is that A is 21, B is 18, C is 17, D is 21 and E is 18. Therefore, all local clusters are more equal clustering than above methods.

This result is shown Table 5. The standard deviation of adaptive cluster member nodes shows that the proposed method is the best.

Random cluster selection		ACHS		The proposed method	
A	21*	A	21*	A	21*
B	16	B	18*	B	18*
C	14	C	10	C	14
D	21*	D	22*	D	21*
E	23	E	24	E	23
stdev	3.4	stdev	4.9	stedv	3.1

Table 1. The number of member nodes in a local cluster

Procedure reselecting cluster head
Input   selected cluster head id
Output   reselected cluster head id

If selected cluster head id Then
   Begin
     If the optimal number of cluster heads
       become EC
     Else
       check Diff=difference between SCH and FMN
      If Diff=0
       become EC
      If Diff>0
       select farther FMN from SCH
       move to SCH as far as Diff-hop(s)
      If Diff<0
       select farther SCH from FMN
       move to FMN as far as Diff-hop(s)
   End

EC   Equal cluster
FMN the farthest member node
SCH the shortest cluster head

Fig. 6. Pseudo code for improved clustering

In pseudo code of Fig. 6, if the node are elected as a cluster head, it determine to have the adaptive member nodes. If it has the adaptive member nodes, the node, the current cluster head, is not changed. If it not, it determine to change the replacement of cluster heads considering three conditions. The three conditions are same to the direct communication conditions. However, in case the replacement of cluster heads have same distance, the proposed method always selects the node far from the current CH.

4. Performance evaluation and analysis

4.1 Energy model for sensor networks

We assumes the sensor energy model for radio hardware energy dissipation, like figure 10. This model can divide the transmitter energy to run the radio electronics and the power amplifier, and the receiver energy to run the radio electronics and have two channel model: the free space (d^2, distance, power loss) and the multipath fading(d^4 power loss) channel models. This model depends on the distance between the transmitter and receiver(Rappaport, 1996). Power control can be used to invert this loss by appropriately setting the power amplifier. if the distance is less than a threshold d0, the free space (fs) model is used; otherwise, the multipath(mp) model is used. Thus, to transmit an l-bit message a distance d, the radio expends
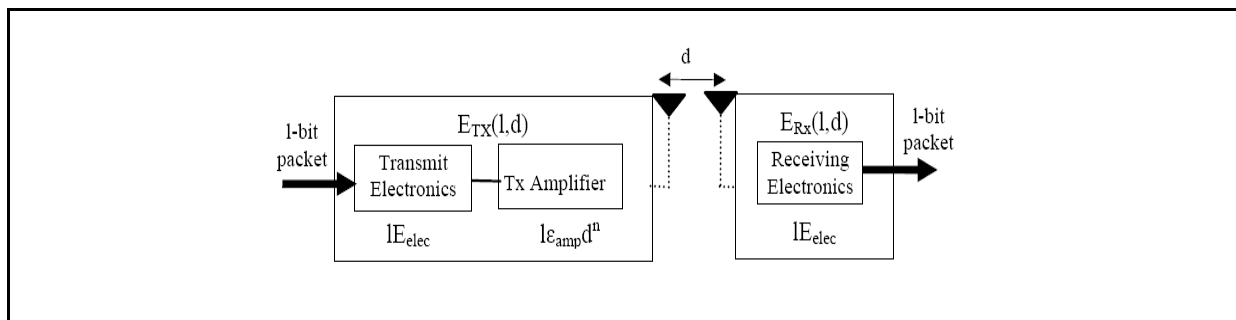
Fig. 7. Radio energy dissipation model

$$E_{Tx}(l,d) = E_{Tx-elec}(l) - E_{Tx-amp}(l,d)$$
$$= \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2, & d < d_0 \\ lE_{elec} + l\varepsilon_{fs}d^4, & d >= d_0 \end{cases} \tag{4}$$

and to receive this message the radio expends:

$$E_{Rx}(l) = E_{Rx} - E_{elec}(l) = lE_{elec} \tag{5}$$

The electronics energy, E_{elec}, depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, whereas the amplifier energy, $e_{fs}d^2$ or $e_{mp}d^4$, depends on the distance to the receiver and the acceptable bit-error rate. for the experiments described in this paper, the communication energy parameters are set as E_{elec}=50nJ/bit, e_{fs}=10pJ/bit/m^2 and e_{mp}=0.0013pJ/bit/m^4. Using previous experimental results(Wang et al, 1999), the energy for data aggregation is set as EDA=5nJ/bit/signal.

If the minimum distance of the multipath channel is same to the maximum distance of the free channel, we can know the minimum distance of the multipath channel by the following equation.

$$lE_{elec} + l\varepsilon_{mp}d^4 = lE_{elec} + l\varepsilon_{fs}d^2$$
$$l\varepsilon_{mp}d^4 = l\varepsilon_{fs}d^2$$
$$d = 87.705 \tag{6}$$

Above equation (6), the minimum channel of the multipath channel is about 87.7m. However, as the transmission range of regular sensor nodes is shorter than it, the channel of WSNs should be the free channel based on multi-hop routing

4.2 Network model for sensor networks

For network configuration, we assume the following network topology, as described in Table 4. We set up the size of the networks to be 100 meter x 100 meter, with a possible communication radius of a node, R, at 10 meters. To prevent an isolation node, the number of network nodes is 300. The sensor node's initial energy is 1 J (Joule) and the data packets of a node are 525 bytes between a cluster-head and member node, and a sink and a cluster-head. As described previously, a sink node is located outside of the sensor networks with the distance between a sink and the networks defined as R. It is shown in table 2.

Network size	100 m²
The nmber of sensor nodes, N	300
Radius of sensor	10m
Length of each packet	525bytes
E_{elec}	50nJ/bit
E_{amp}	10pJ/bit/m²
EDA	5nJ/bit

Table 2. The number of member nodes in a local cluster

4.3 Analysis for cluster head capacity

When frist round, the proposed method is almost equal to a previous method. Thus we will compare the average energy consumption of nodes when r>1. We assume that '1' round time is the time to select cluster head 20 times. In figure 12, gray dots show the nodes when using the cluster head selection method of LEACH and black dots when proposed method. When using proposed method, the average round of nodes is higher. That means that the energy re-selected nodes are lower than other node's energy and the energy distribution is good by selecting the node with the lowest remaining energy.
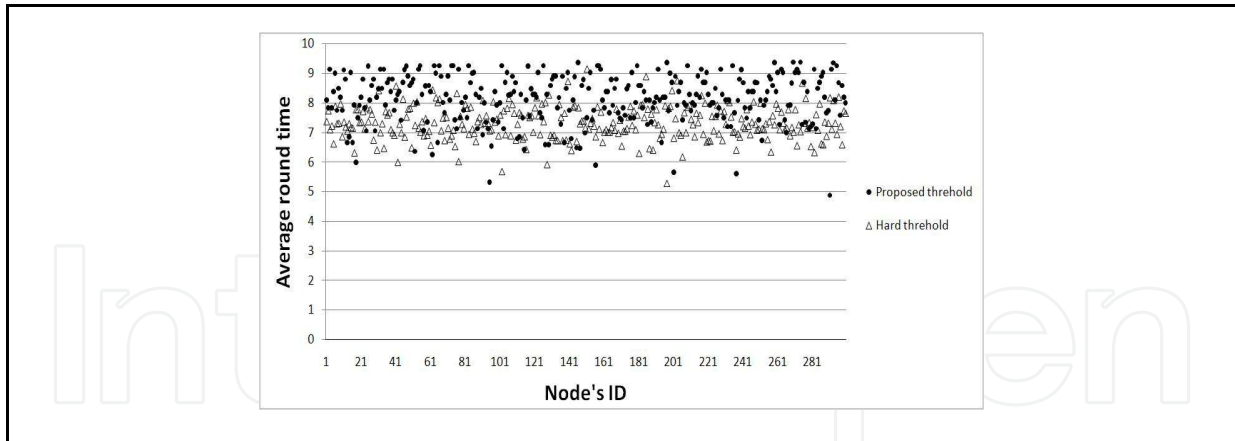
Fig. 8. Average round time of nodes

Fig. 9 shows survival rate of nodes. Node alive rounds of proposed method are longer than the method like LEACH. That means that LEACH cannot control to distribute overload of a cluster head. As the proposed method considered unequal clustering, overload of a cluster head, the nodes that used this method live longer than LEACH. As the round progresses, we can know survival rate of the proposed method is higher than LEACH. Since the percentage of alive nodes are 90%(0.9), the nodes of LEACH dramatically died than the proposed method. When the alive rate is 10%(0.1), they died slowly as the remaining nodes have few member nodes. Since 90%, the nodes of the proposed method, on the other hand, died slowly than LEACH as distributing energy consumption.
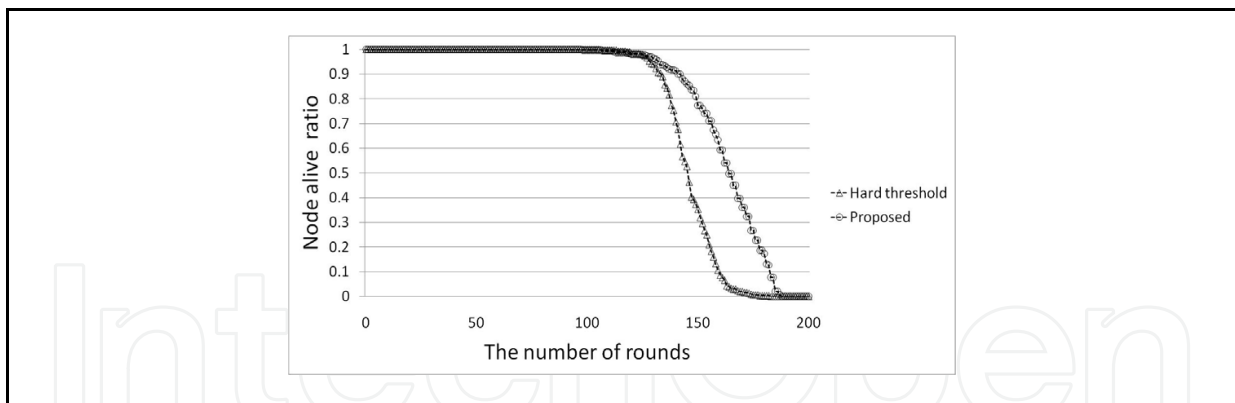
Fig. 9. Node alive round

4.4 Analysis of the number of cluster member nodes

We measured the number of member nodes and hop count in local cluster. Each node is chosen for a cluster head with equal probability. After cluster head election about 20 times, one round comes to an end. We repeated this process 10 times. We gained the result of average value and obtained the standard deviation of standard variation and clustering. The lower standard deviation, the more equal a cluster forms.
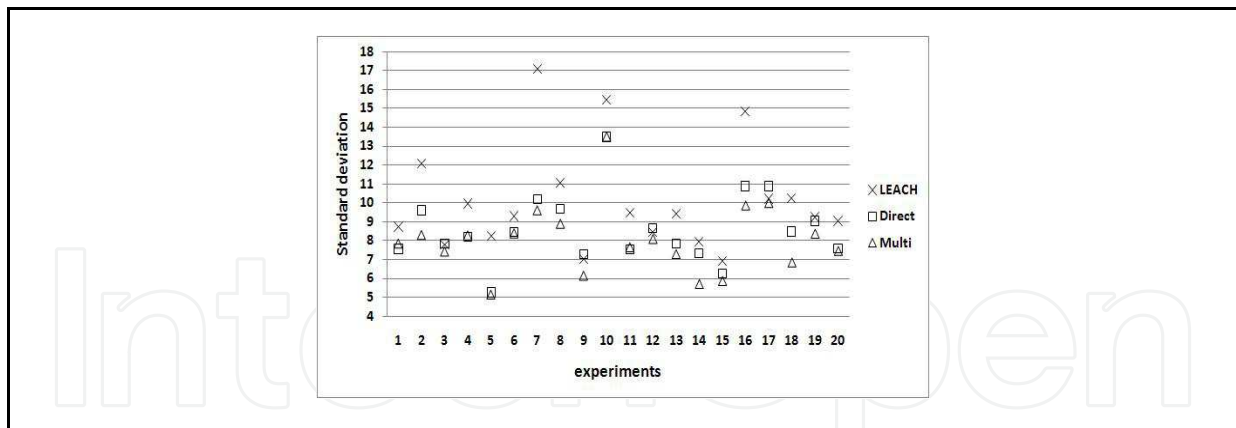
Fig. 10. The standard deviation of member nodes

Fig. 10 shows the standard deviation (STDEV) of member nodes in local cluster. Above figure, LEACH is higher than other algorithm. On the other hand, Direct(direct communication) and Multi-hop(multi-hop communication) are lower than LEACH. In case of the standard deviation of LEACH, experiments number 2, 7 and 16, a cluster is bad-case-scenario. In bad-case, Direct and Multi-hop can reduce STDEV of member nodes. In experiments number 3, 9 and 12, Direct is higher than LEACH. This means that Direct can form unequal clustering, compared with cluster formation. In case of the proposed method Multi-hop, it has little lower value than LEACH and Direct. Also, as shown in Fig. 11, Multi-hop has the lowest average standard deviation value of member nodes. So, Multi-hop can organize more equal cluster size than LEACH and Direct.
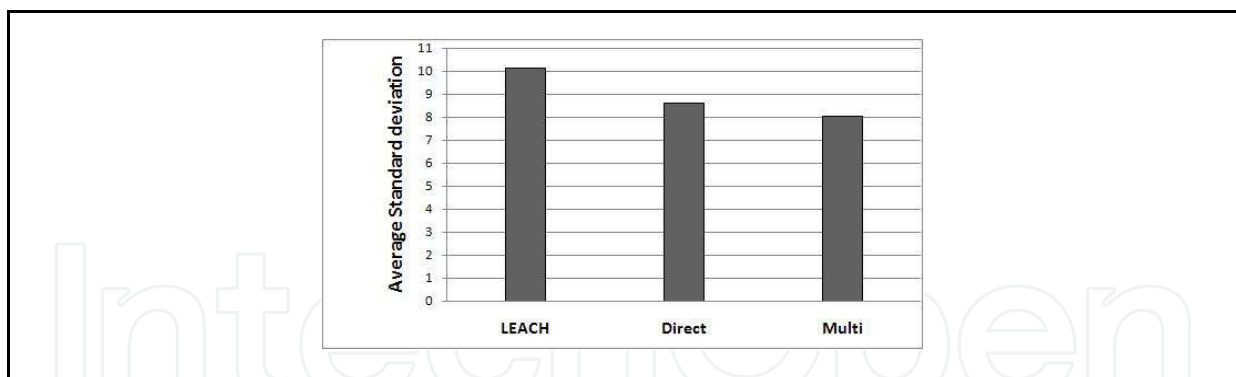
Fig. 11. The average standard deviation of member nodes

Although a cluster is formed equally, if it is long distance between a cluster head and nodes, communication cost between two nodes is increased. And we measured the average hop count of local cluster. As a result figure 24, Multi-hop has lower hop count value than LEACH and Direct. This means that Multi-hop reduces the distance between a cluster head and member nodes and communication cost of sensor nodes and a cluster head in local cluster. So, Multi-hop can form a cluster that has the adaptive member nodes and reduce energy consumption of whole sensor networks.

4.5 Finding optimal number of member nodes

We assume the number of optimal member nodes is (N/CHnum-1). We make an experiment on the standard deviation per a local cluster and the energy consumption of member nodes. In experiment, we configure the optimal member nodes as 5%~100% among member nodes and measure the energy efficiency of a local cluster.
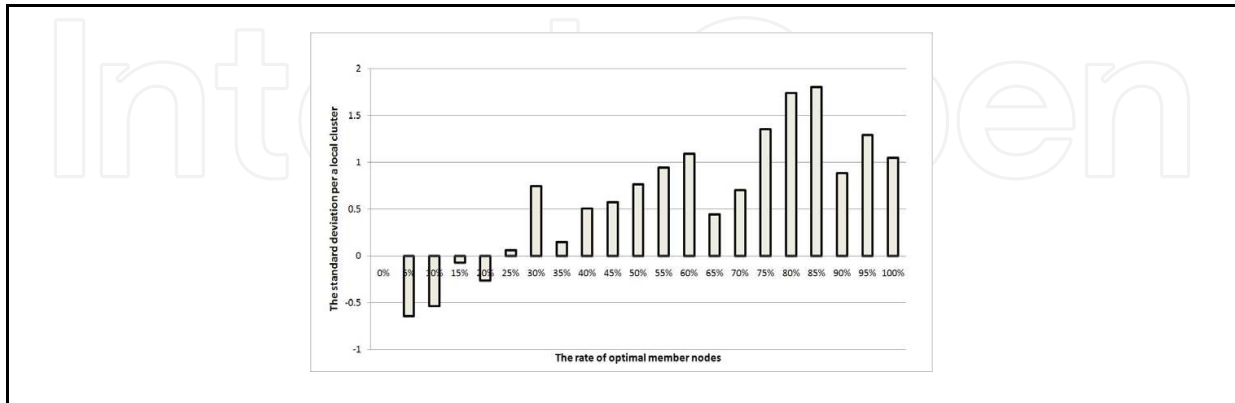

Fig. 12. Comparing with standard deviation of member nodes

Fig. 12 shows the standard deviation per a local cluster as increased the optimal number of member nodes. If the optimal number is 0%, like the direct communication method, the standard deviation value is zero because the optimal number is same. In case of the number of member nodes between 5 and 20 percent, we can show the standard deviation per a cluster is decreased. The low standard deviation value means more equal clustering and the higher value means low equal clustering. And the low value can decrease the amount of data packet.
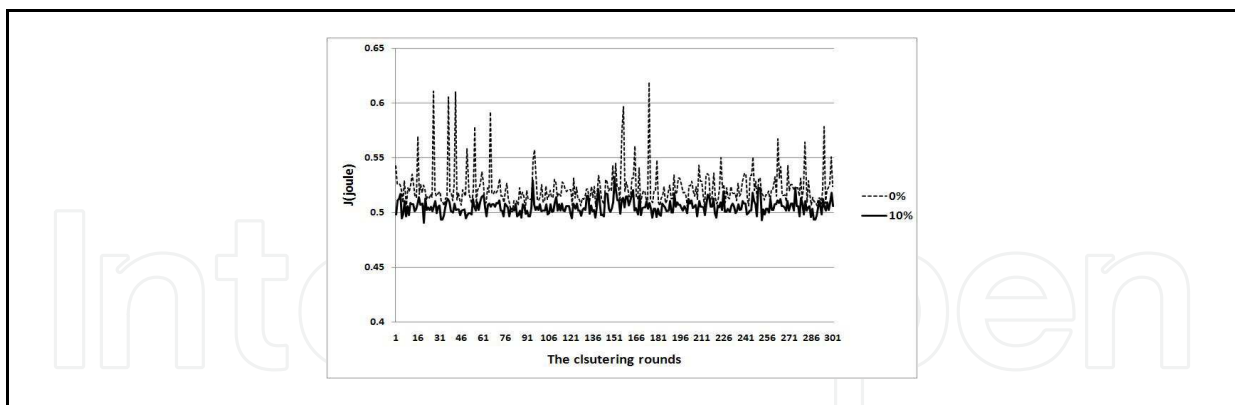
Fig. 13. Energy consumption for clustering

Fig. 13 shows comparing 0% and 10%. The 10% has lower energy consumption than 0%. The reason is as following. First reason is more permissible range. Second reason is more equal member nodes. Third reason is less data packet. Fourth reason is energy distribution.

5. Conclusion

This thesis proposed new optimized clustering algorithm through cluster head selection focused on reducing energy consumption of local clusters and overall networks. It elected the cluster head among nodes which are possible for the cluster head and proved the energy efficiency by comparing previous methods. It is performed by the network scalability and energy consumption. To achieve this, we obtained the energy consumption in Intra-cluster and Inter-cluster, and then we could find the average energy of overall network. Finally, we proposed the re-electing cluster heads method for balancing local clusters. This method uses the information which the cluster heads have. This information is the number of member nodes and distance between the member nodes and the cluster head. Thus the new cluster heads can be elected by this information.

Further works will be intended to compare and analyze the above the methods, and find the optimization clustering algorithm. To achieve this, we have to perform the experiments which are load balancing between member nodes and local clusters, and fault-tolerance in Intra-cluster and Inter-cluster. For load balancing, we would calculate the number of packets from nodes and the packet success ration of sensing data. And for fault-tolerance we would measure the data delay time of sensing data and prove the strong connectivity, which is an means of supplementing route path when the node failure. Through these experiments, we will find the optimization clustering algorithm in WSNs.

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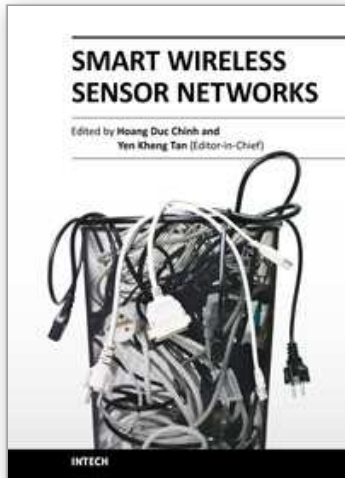
Smart Wireless Sensor Networks

Edited by Yen Kheng Tan

The recent development of communication and sensor technology results in the growth of a new attractive and challenging area â€" wireless sensor networks (WSNs). A wireless sensor network which consists of a large number of sensor nodes is deployed in environmental fields to serve various applications. Facilitated with the ability of wireless communication and intelligent computation, these nodes become smart sensors which do not only perceive ambient physical parameters but also be able to process information, cooperate with each other and self-organize into the network. These new features assist the sensor nodes as well as the network to operate more efficiently in terms of both data acquisition and energy consumption. Special purposes of the applications require design and operation of WSNs different from conventional networks such as the internet. The network design must take into account of the objectives of specific applications. The nature of deployed environment must be considered. The limited of sensor nodesâ€™ resources such as memory, computational ability, communication bandwidth and energy source are the challenges in network design. A smart wireless sensor network must be able to deal with these constraints as well as to guarantee the connectivity, coverage, reliability and security of networkâ€™s operation for a maximized lifetime. This book discusses various aspects of designing such smart wireless sensor networks. Main topics includes: design methodologies, network protocols and algorithms, quality of service management, coverage optimization, time synchronization and security techniques for sensor networks.

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