Study on Use of a Clustering Technique with Zone-Based Multi-hop Communication in Wireless Sensor Networks

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Abstract

In Wireless Sensor Networks (WSNs), the most important issue is to expand life time of network with the restricted energy resource of sensor nodes. Sensor nodes consume mostly energy when they transmit and receive sensing data. Thus it is important that how to set up a communication method of sensor networks. Generally, to achieve this is a clustering technique. A clustering technique is a communication method which can classify the area by nodes with same or similar sensing and prevent duplicated sensing data to reduce communication. And it can manage sensing data when working locally. To use a clustering technique, the environment to build clustering has to be considered, which means cluster heads counts can affect clustering formation. Thus, this paper proposes use of a clustering technique with zone-based multi-hop communication in WSNs.

Keywords: *Wireless sensor network, multi-hop manner, clustering technique, zone-based communication*

1. Introduction

Wireless Sensor Networks (WSNs) are made of large number of tiny sensor nodes, which have the restricted resource and transmit environmental information using self-organized networks [1, 2]. Sensor nodes consist of three modules: a sensor module which detects the surrounding environment, wireless module which communicates with neighbor nodes and a process module which process sensing data. For self-organized networks, they have to establish networks by using the ad-hoc communication technique [3]. Although ad-hoc networks focus on mobility of nodes, WSNs focus on the most efficient use of the available energy resources like expanding network life time. To achieve this, many mechanisms and models have been proposed [4]. Among the many methods, a clustering technique is proposed for network life time, network scalability and load balancing with each node [5]. A clustering technique is a communication method which can classify the area by nodes with same or similar sensing and prevent duplicated sensing data to reduce communication. And it can manage sensing data when working locally. The local cluster consists of member nodes which detect the surrounding environment and a cluster head which collects and aggregates sensing data from member nodes. A cluster head can cause more additional costs of aggregation, transmission and analysis of and consume more energy than member nodes. The communication method between a cluster head and member nodes can use multi-hop manner. Network size of WSNs should be small to communicate direct to a sink node because communication radius of sensor nodes is restricted to 10m (meter) in 802.15.4 [6]. However, WSNs have to use multi-hop manner through neighbor nodes as normal sensor networks cover huge area beyond the communication scope of nodes. When using multi-hop communication, energy consumption of sensor nodes occur form transmission-bits and receive-bits [7, 8]. Transmission-bits are caused by node which sends sensing data and receive-bits by node which receives sensing data from transmission nodes. Receive-bits are more than transmission-bits because all nodes which are located in communication range of a transmission node can receive sensing data from a transmission node. Thus, this paper propose conditions of clustering formation by comparing of transmission-bits and receive-bits considering communication features of sensor node and calculating energy consumption of WSNs. These results show standard of energy efficient clustering formation.

The structure of this paper is as follows. In section 2, we describe modeling of the clustering- and non-clustering algorithm. In section 3, we describe the performance evaluation and analysis of the proposed method by revised equation. Finally, in section 4, we conclude this paper.

2. Communication Modeling of Clustering and Non-clustering

Generally, in non-clustering, each sensor node uses multi-hop communication to transmit detected sensing data to a sink node. Thus, the amount of sensing data is dependent on distance, hop-counts, between a sink and nodes. On the other hand, in clustering, member nodes of a local cluster only transmit sensing data to own cluster head. A cluster head collects, aggregates and analyzes sensing data and transmits the aggregated data to a sink node. Thus, the amount of sensing data is dependent on distance between member nodes and a cluster head and distance between cluster heads and a sink node. The distance is depending cluster size which is determined by the number of cluster heads. To compare two cases, clustering and non-clustering, we set up the environment as shown in Figure 1.

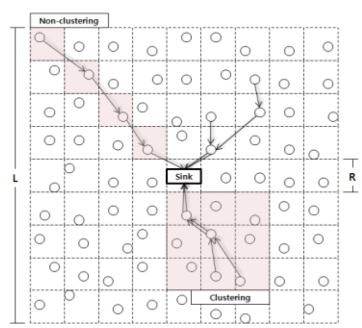

Figure 1. Comparing of Clustering and Non-clusteirng Transmission Methods

This environment is same to previous environment like cluster vs non-cluster [9]. And the following assumptions are applied.

1) There are Q sensor nodes in the networks.
2) There is only one node in RxR size, $R=[0,L]^2$.
3) Each node can directly communicate with neighbor nodes which is 8 cells.
4) Each node transmits m-bit report message to neighbor nodes or a cluster head.
5) A cluster head can aggregate m-bit report messages from member nodes and transmit m-bit message to a sink node.

To calculate energy of non-clustering and clustering, we use the bit-hop metric [10]. The bit-hop metric uses BT, the total number of Bit Transmission in the network. ET-bit, the energy consumed for transmitting one bit of data, shows 1 J and ER-bit, the energy consumed for reception of one bit of data, is 0.5 J. These equations are as follows.

$$E_t = BT * E_{T\text{-}bit} \quad (1)$$

$$E_r = BT * E_{R\text{-}bit} \quad (2)$$

From equation (1) and (2), the total energy cost of the network(E) is as following :

$$E = E_t + E_r = BT * (E_{T\text{-}bit} + E_{R\text{-}bit}) \quad (3)$$

Above equations, the value of BT is same when transmission and reception. However, transmission BT and reception BT is different.

Like Figure 2, when nodes transmit sensing data to neighbor nodes, BT of transmission, BT (Transmit), is only one cell, but BT of reception, BT (Receive), is 8 cells. Thus, like equation (2) and (3), BT of transmission and reception cannot be equal. To revise this problem, we define new BT (Transmit) and BT (Receive). In Figure 1), we do not revise BT(Transmit) which is same to BT. However, like Figure 3, we find out BT(Receive) is dependent on network size. To achieve this, new BT (Receive) equation is derived from appendix A of cluster vs non cluster [9]. In case of network size is 3x3, the total BT(Receive) is 4*a + 4*b+0*c, in case of 5x5, 4*a+12*b+9*c, in case of 7x7, 4*a +20*b+25*c, …, In case of $\sqrt{N} * \sqrt{N}$, 4*a+4*($\sqrt{N}$-2)*b+($\sqrt{N}$-2)^2*c. In Figure 3, if transmission node is located in 'a', BT (Receive) is 3, b is 5 and c is 8. So, BT (Receive) is 4*a+4*($\sqrt{N}$-2)*b+($\sqrt{N}$-2)^2*c. If this equation is simple enough, this is as following.

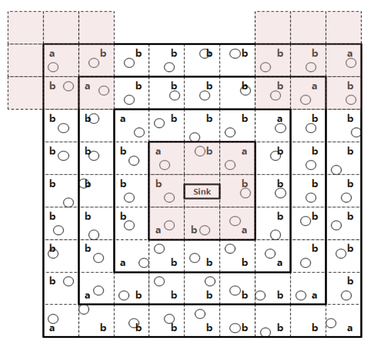

Figure 2. BT-receive Area Dependent on Location of a Sensor Node

Non-clsutering:.

$$BT(Transmit): Q*n*m \quad (4)$$

$$BT(Receive): 4(2N-3\sqrt{N}+1)*m \quad (5)$$

Clustering :

$$BT(Receive): 4(2N-3\sqrt{N}+1)*m/(Q-1)*c + p*(Q-1-c)*4(2N-3\sqrt{N}+1)*m/(Q-1) \quad (6)$$

3. Performance Analysis of Clustering and Non-clustering

We compare clustering and non-clustering by using new equation of sensor communication bits. First, we set up the network environment like cluster vs non cluster [9] to understand previous results and proposed results easily. In case of network size, $\sqrt{N}$, is 300 in non-clustering, BT(Receive) and BT(Transmit) is shown in Figure 3.

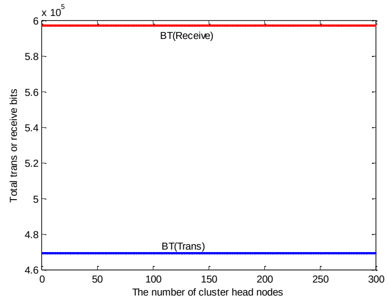

Figure 3. BT (Transmit) vs BT (Receive) when Non-clustering

BT (Transmit) is lower than BT (Receive) because reception node is more than transmission node. That means that energy consumption of non-clustering is dependent on BT (Receive) than BT (Transmission). So, it is important to obtain BT (Receive). BT (Transmit) and BT (Receive) of clustering are shown Figure 4.

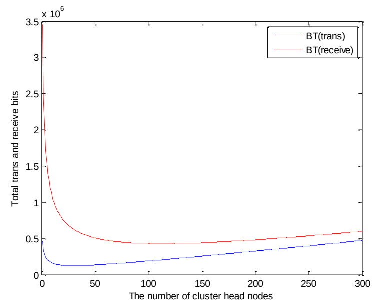

Figure 4. BT (Transmit) vs BT (Receive) when Clustering

In clustering, BT (Receive) is also higher than BT (Transmit). Especially, when the number of cluster heads is under 20, the gap of BT (Receive) and BT (Transmit) is more higher. As BT (Receive) affects energy consumption of WSNs, it is important to set up the optimal number of cluster heads. In Figure 4, in case there is not any cluster heads, this means that this situation is same to non-clustering. So, BT (Receive) is the highest. On the other hand, in case there are more than 10% of cluster heads, BT (Receive) is lower than under 10% of cluster heads. Although the cluster heads count is increased over 10%, BT (Receive) is little changed. We figure out difference between previous and proposed equations by energy consumption. This is shown in Figure 5.

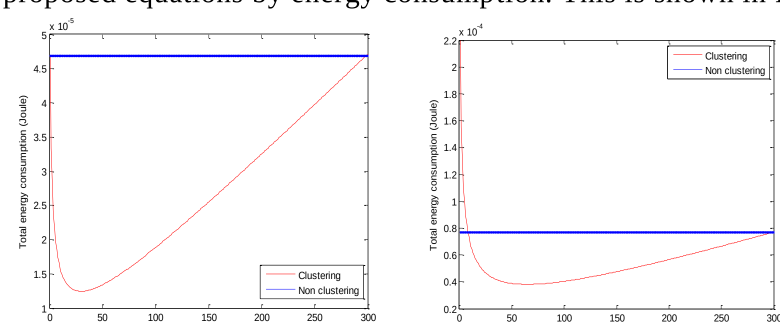

Figure 6. (L) Previous Energy Consumption vs (R) Proposed Energy Consumption

In Figure 5 (L), clustering is always is lower energy consumption than non-clustering. However, as this result does not apply BT (Receive), this is not to be trusted. In Figure 5 (R), clustering is lower energy consumption than non-clustering when the number of cluster heads is more than 10%. This means that if the number of cluster heads is not 10%, the distance between member nodes and a cluster head is longer than the distance between a sink and sensor nodes. The proposed equations present more accurate results because adding BT (Receive). This helps present energy change according to increase of cluster heads. Figure 7 shows and compares only clustering in Figure 6. Energy variation rate of clustering with BT (Receive) is higher than without BT (Receive).

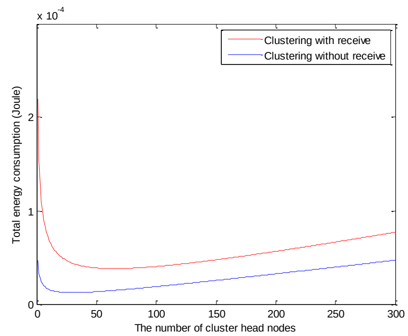

Figure 6. Compared of clustering BT (Receive) vs clustering without BT (Receive)

The above results is based on the networks size, $\sqrt{N}$, is 300. To find the optimal number of cluster heads in clustering, we need to compare the optimal number of cluster heads depending on network size.

4. Conclusion

The clustering technique of WSNs is communication method to improve network life time, network scalability and load balancing. However, if a clustering technique is applied without considering reception energy of nodes, clustering is not better than non-clustering. Thus, we proposed the extended energy modeling of clustering in WSNs. To achieve this, we applied reception energy of nodes to energy equations and suggested network environment for comparing of clustering and non-clustering. Above results, in case of the 10% cluster heads, we found clustering is more energy efficient method than non-clustering.

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