An Algorithm for WSN Routing Protocol in Smart Building Systems

Hnin Yu Shwe ,Peter Han Joo Chong
School of Electrical & Electronic Engineering
Nanyang Technological University, Singapore
hninyushwe@ntu.edu.sg

Abstract

Now a day, wireless sensor networks play a key role in smart building systems by providing the "real-time" information to the system. In resource constrained wireless sensor networks, it isvery important to design the protocols with energy efficiencyin order to prolong the lifetime of the sensor networks. Node clusteringand data aggregation become popular since cluster-based sensornetwork can enhance the whole network throughput by aggregatingthe collected sensory information in each cluster. In sucha network, the cluster head nodes play an important role inforwarding data originated from other common nodes to the sink.As a consequence, the cluster head nodes will have the problem ofquick energy depletion upon multiple packets forwarding in highdata load sensor networks. In this paper, we proposed an algorithm for routing protocol which is an integration of clustering and routing in wireless sensor networks. Simulationresults are provided to show the efficacy of the proposed methodin terms of the throughput and end-to-end delay.

1. Introduction

Wireless sensor networks (WSNs) will be responsible forthe majority of the growth in smart building systems over thenext decade. Smart building systems are becoming more andmore vital due to the improvement they provide to the qualityof life. As we can see in Fig. 1, one of the key components of asmart building system is a sensor network, which provides thenecessary information to the smart building system, allowingit to control and respond to the real-time demand.

A WSN is formed by a large number of sensor nodes to monitor the objects of interest or environmental conditions such as sound, temperature, light intensity, humidity, pressure, motion and so on through wireless communications [1]. As the technology of WSN matures, the scope of their applications has become more extensive, e.g., environmental monitoring, home automation, intelligent office, energy saving, intelligent transportation, health care, and security monitoring [2].

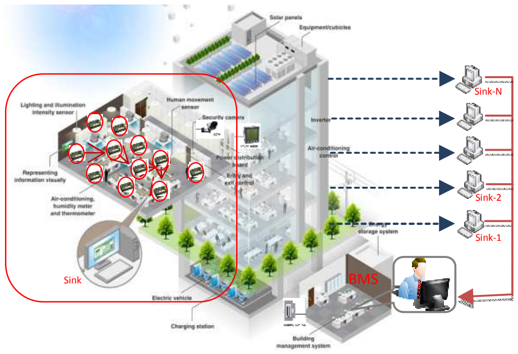


Figure 1. Sensor network in smart building.

A major limitation of untethered nodes is finite battery capacity and memory and thus power efficient configuration of WSN has become a major design goal to improve the performance of the network. Due to the limited resources of sensor nodes, it is very important to design a routing protocol with energy efficiency to extend the lifetime of the WSN. Several solution techniques have been proposed to maximize the lifetime of battery-powered sensor nodes. Among the various techniques, it is well-known that cluster architecture enables better resource allocation and helps to improve power control.

In the clustered environment, the data gathered by the sensors are communicated to the base station (BS) through a hierarchy of cluster-head (CH) nodes [3]. With clustering in WSN, the randomly distributed sensor nodes are formed as many clusters and each sensor node has to transmit the collected data to its CH. After deployment, the CH is responsible for collecting data from its cluster member sensors, and those collected sensor data are aggregated and then forwarded to the BS via the sink [4] [5].

Thus, the CH plays an important role in aggregating and forwarding data sensed by other common nodes and as a consequence CH consumes more energy than the other member sensors. In addition, another limitation of the sensor node is the buffer size and it is also very important to efficiently utilize the limited buffer of the sensors. In this paper, we propose architecture of multi-level cluster-based WSN and routing algorithm to optimize the throughput and delay of high data load sensor networks.

The remaining of this paper is organized as follows. We first discuss the related works in Section 2. We then briefly present our proposed network architecture in Section 3. Simulation results and discussions are presented in Section 4. Finally, we conclude our paper and present our future work in Section 5.

2. Related Works

WSNs are event-based systems based on the collaboration of several micro-sensor nodes [6]. The high density of sensor nodes is vital for sensing, intrusion detection, and tracking applications. When an event is detected in the network, the aggregated collaborative report of the detecting nodes is delivered to the sink. Clustering mechanisms enable the sensor nodes to collect and aggregate data at nodes called CHs in each cluster. However, due to the high data load nature of monitoring sensor networks, the cluster head nodes will suffer from the problem of packet overwhelming over the time [7].

Since the packet transmission is the most power consuming action for sensor nodes and the network coding technique reduces the number of packet transmissions, network coding becomes useful to reduce the energy consumption in WSN. Network coding technique [8] allows cluster head node to produce the linear combination of the received packets from its cluster member nodes before sending the data to the sink. The operations are computed in the finite field and thus the result of the operation is also of the same length. The original packets can be recovered at the sink by solving the set of linear equations just after receiving the required number of linearly independent packets [9] [10].

3. Proposed Method

In this section, we will illustrate the network model of our study. We consider a simple cluster-based monitoring WSN where hundreds of sensor nodes generate the readings on every unit time and those sensory data are sent to the sink via CH. The network architecture of our proposed multi-level cluster-based WSN is illustrated in Fig. 2. As it can be seen in the figure, we logically consider the network as 2-level network. In level-1, the whole network is broken into set of clusters and member nodes send data to associated CH. In level-2, data communication is carrying out only among CHs in order to forward data to BS.

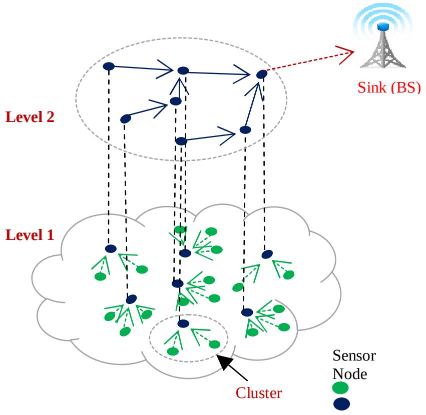
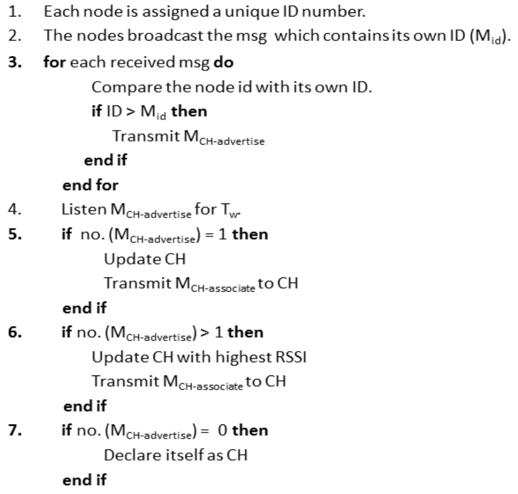


Figure 2. Architecture of proposed protocol.

Our proposed system can be mainly classified into two phases:

(1) Cluster forming phase, and
(2) Data collection phase.

(1) *Cluster Forming Phase*:



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1.  Each node is assigned a unique ID number.
2.  The nodes broadcast the msg which contains its own ID (M_id).
3.  for each received msg do
          Compare the node id with its own ID.
          if ID > M_id then
             Transmit M_CH-advertise
         end if
      end for
4.    Listen M_CH-advertise for T_w.
5.    if no. (M_CH-advertise) = 1 then
            Update CH
            Transmit M_CH-associate to CH
      end if
6.    if no. (M_CH-advertise) > 1 then
          Update CH with highest RSSI
          Transmit M_CH-associate to CH
      end if
7.    if no. (M_CH-advertise) = 0 then
            Declare itself as CH
      end if
```

Figure 3. Algorithm of cluster forming.

After all nodes are deployed, clusters are formed according to the algorithm shown in Fig. 3. In our algorithm, CH nodes are chosen based on the highest node ID (HID) and the received signal strength (RSSI). We assume that each sensor node has its own ID. In the beginning of the clustering phase, the nodes broadcast the message which contains its own ID. Due to the broadcast nature of the sensor networks, all the nodes in its communication range will receive that message. For each received message, the node will compare the embedded ID with its own ID. If a node found that its own ID is greater than the entire received ID, it will broadcast the cluster head advertisement message ($M_{CH\_advertise}$). Entire nodes in the network will listen to the cluster head advertisement for the unit time T_w.

After time T_w, if a node receives only one cluster head advertisement message, it means no.($M_{CH\_advertise}$)=1, it joins in that cluster and sends cluster head associate message ($M_{CH\_associate}$) back to that CH node then it updates its associate cluster head node. For the nodes who received more than one cluster head advertisement message, it means no.($M_{CH\_advertise}$)>1, sensor node decides which cluster to join based on the received signals strength. After choosing the cluster head, it sends cluster head associate message ($M_{CH\_associate}$)back to that CH node then it updates its associate cluster head node. For the nodes who did not receive any cluster head advertisement message in T_w, it means no.($M_{CH\_advertise}$)=0, it advertises itself as cluster head and form an isolated cluster. After joining cluster, sensor nodes send their data only to the associated CH node. In our cluster forming phase, we ensure that every node in the same cluster is in one-hop distance.

(2) *Data Collection Phase*:

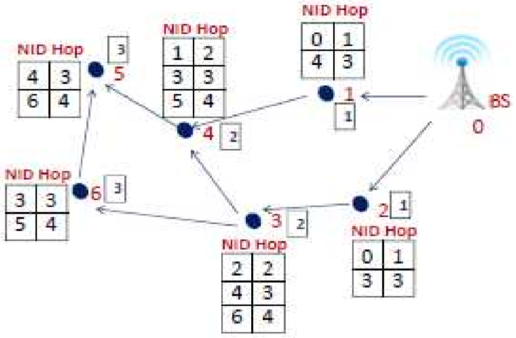
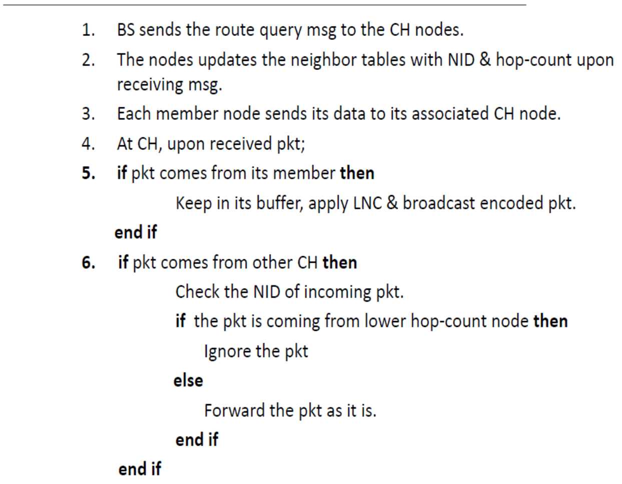


Figure 4. Neighbour table format.

In our approach, in order to avoid loop-back routing, each CH maintains a neighbour table which contains information about ID and hop-to-BS count of neighbouring CHs as shown in Fig. 4. BS initiates the route query message to find out the route in the beginning of the data routing phase. Upon receiving the route query message, each CH updates the neighbour table with neighbour ID (NID) and hop-to-BS entries. From this neighbour table, each CH can be able to know its own hop-count information from BS and updates its own hop-to-BS value as well. For example, in Fig. 4, CH:4 can receive data from its three neighbour CHs; CH:1, CH:3, and CH:5, where the corresponding hop-to-BS are 2, 3, and 4 respectively. In addition, it can be known that CH:4 is 2 hop away from BS, which is obtain as the minimum hop-to-BS number in the neighbour table. With the help of this table, each CH can avoid loop-back data routing by discarding the packets received from lower hop-to-BS nodes. For example, CH:4 will always discard the packets received from CH:1 in order to avoid data loop-back.

After constructing neighbour tables, data routing can be carried out. In our approach, we use different radio transmission range for members and CHs. Since member nodes need only inter-cluster communication, they are assigned the transmission range of 15*m* which is the radius of the cluster. However, CHs need to communicate with neighbouring CHs for data dissemination; their transmission range is double the transmission range of member nodes.

The proposed multi-hop routing works as follow. Each member node sends its sensory data to the associated CH. In our approach, we apply simple linear network coding (LNC) [11] in CH in order to further reduce the energy consumption in data dissemination process. CH performs LNC upon receiving packets from its member nodes and broadcasts the encoded packets. CH also performs as relay in order to forward the data to the next CH and the same process is continued until the data is finally reached to BS. The detail multi-hop routing algorithm can be seen in Fig. 5.



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1. BS sends the route query msg to the CH nodes.
2. The nodes updates the neighbor tables with NID & hop-count upon
   receiving msg.
3. Each member node sends its data to its associated CH node.
4. At CH, upon received pkt;
5. if pkt comes from its member then
       Keep in its buffer, apply LNC & broadcast encoded pkt.
   end if
6. if pkt comes from other CH then
       Check the NID of incoming pkt.
       if the pkt is coming from lower hop-count node then
           Ignore the pkt
       else
           Forward the pkt as it is.
       end if
   end if
```

Figure 5.Multi-hop routing algorithm.

4. Simulation Results

4.1. Simulation Setting

We perform computer simulation using NS-2 [12], a standard tool in sensor network simulation. The detail parameter setting for the simulations is shown in Table 1. In our simulation, we assume sensor nodes are stationary after deployment. All nodes in the network are homogeneous and energy constrained. The location of the sink node fix and far from the sensor network and the data sensed by the sensors can be reached to the sink node via CH nodes. We use CBR (constant bit rate) as traffic source and numbers of sources are 20, 40, 60, 80 and 100 separately.

Table 1.Simulation Parameters.

Parameters Description	***Values***
Simulation Area	100 *m*^{2}
Network Size (nodes)	100
Placement Model	Random
MAC Protocol	802.15.4
Node Movement	Static
Traffic Type	Constant Bit Rate
Data Packet Size	50 Byte
Transmission range (non-CH)	15 *m*
Transmission range (CH)	30 *m*
Channel Type	Channel/wireless
Antenna Mode	Antenna/omniantenna
Simulation Time	500 *s*
Energy Model	MicaZ

4.2. Simulation Results

In order to evaluate the performance of our proposed protocol, we computed the packet delivery ratio and end-to-end delay with a period of 500 seconds under the proposed protocol and compared our proposed scheme with the standard routing protocol, AODV [13][14].

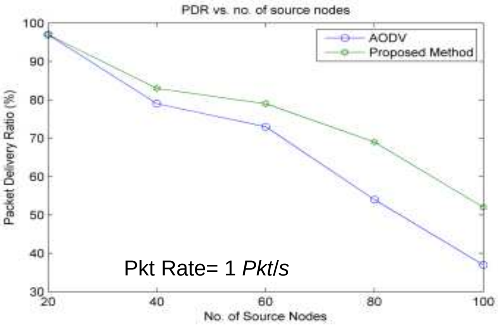

Figure 6. Packet delivery ratio vs. number of source nodes.

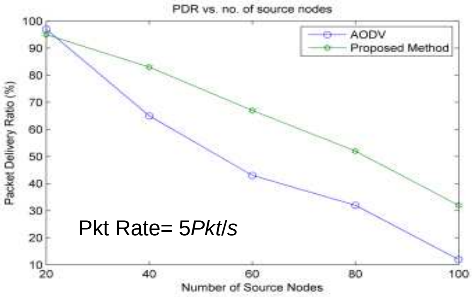

Figure 7. Packet delivery ratio vs. number of source nodes.

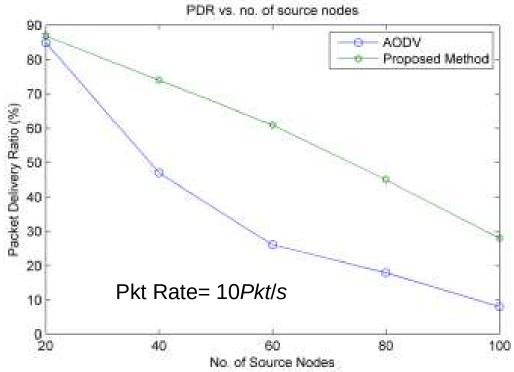

Figure 8. FPacket delivery ratio vs. number of source nodes.

Fig. 6,Fig. 7 and Fig. 8 show the simulation results of packet delivery rate on different number of source nodes. This measurement was done assuming each sensor node in the network has fixed buffer size of 10. As we can see from the figures, the packet delivery ratio of our proposed method is higher than AODV in various number of source nodes. Although the performance is not very significant in low packet rate (1 Pkt/s), we can see the significant results in packet rate of 5 Pkt/s and 10 Pkt/s.

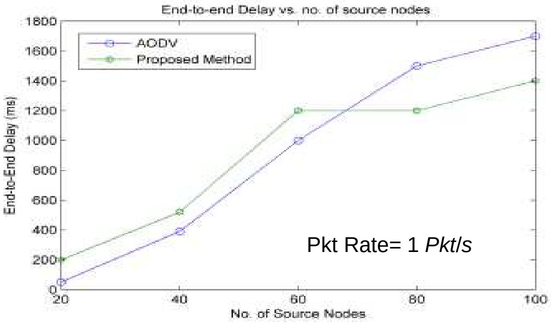

Figure 9.End-to-end delay vs. number of source nodes.

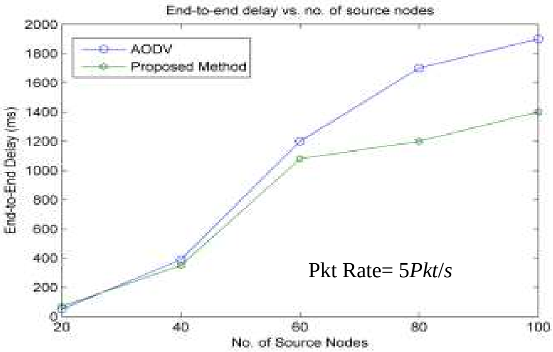

Figure 10. End-to-end delay vs. number of source nodes.

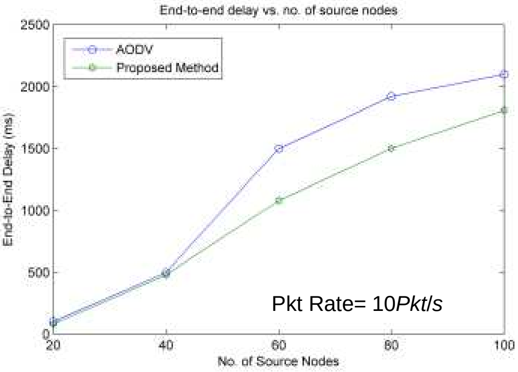

Figure 11. End-to-end delay vs. number of source nodes.

We then plot the end-to-end delay as a function of the number of source nodes. Fig. 9,Fig. 10 and Fig. 11compare the average delay between our proposed protocol and AODV during the simulation time. In Fig. 9, under low packet rate which is 1 Pkt/s, our proposed protocol has moredelay than AODV for the number of sources less than 60. This is because the CH node keeps the data packet until it receives enough packets to encode. However, when load becomes heavy which is greater than 60 sources, the performance of our proposed protocol becomes better.

In Fig. 10 and Fig. 11, even though the performance of our proposed protocol and AODV is not much different for sources less than 40, it is obvious to see that our proposed protocol outperform AODV for the heavy load which is sources greater than 60.

From the results, we conclude that our proposed protocol is able to optimize the packet delivery ratio and end-to-end delay for the heavy load sensor networks.

5. Conclusion

In this paper, architecture of multi-level cluster-based routing algorithm for WSN was introduced and discussed. The basis of our protocol is using linear network coding only at the CH nodes in order to increase the throughput of the whole sensor network. Since only CH nodes perform dataencoding and take responsibility to send the data to the sink node, it causes energy saving of member sensor nodes. Simulation results show that our proposed scheme outperform AODV in terms of PDR and end-to-end delay. In the future, we will research on the energy consumption and lifetime of the network.

Acknowledgment

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