Maximizing the Lifetime of Clustered Wireless Sensor Network VIA Cooperative Communication

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ABSTRACT

Wireless Sensor Networks are networks of tiny, battery powered sensor nodes with limited on-board processing, storage and radio capabilities. Sensor nodes sense and send their data toward a processing center called sink. The design of such networks has to be energy aware in order to prolong the lifetime of the network, because the replacement of the embedded batteries is a very difficult process once these nodes have been deployed. In a clustered Wireless Sensor Network the data is forwarded from non-Cluster Head sensor node to Cluster Head sensor node. The distance is large for Inter distance communication (distance between two Cluster Heads) when compare to Intra distance communication (distance between non-Cluster Head to Cluster Heads). Hence the message transfer between two Cluster Heads is via cooperative nodes. Sensors node that have highest energy will participate in cooperative communication. The cooperative communication and Cluster Head nodes are active throughout the network lifetime. Limited energy and difficulty in recharging a large number of sensor nodes, energy efficiency and maximizing network lifetime is a design issue for Wireless Sensor Networks (WSN) with battery-operated nodes: So the sensor node other than Cluster Head node and cooperative communication nodes should be switched between sleep and wakeup mode to extend the life of Wireless Sensor Network. The simulation results have confirmed that the proposed sleep and wakeup procedure scheme significantly improves the energy consumption.

KEYWORDS: lifetime maximizaiton, sleep and wakeup procedure, Cooperative communication, Cluster, Wireless Sensor Network.

I. INTRODUCTION

Wireless Sensor Network (WSN) comprises of hundreds to thousands of small nodes employed in a wide range of data gathering applications such as military, environmental monitoring etc.

The Wireless Sensor Networks have received tremendous attention from both academic and industry. Wireless Sensor Networks are now being widely tested and deployed for different application domains [1]. The existing applications include environmental monitoring, industrial sensing and diagnostics, health care, and data collecting for battlefield awareness. Most of the applications are developed by using low-rate, short distance and low-cost wireless technologies.

A sensor network consists of sensors nodes, each of which has a limited communication range and a limited energy supply in the
form of a battery. If two sensors are neighbors in the transmission range of each other can directly communicate with each other, the sensor node periodically generates a data sample to communicate with the sink. The sink may not be within direct communication range, sensor nodes data has to be forwarded to the sink through intermediate sensor nodes.

The typical model for clustered Wireless Sensor Network is depicted in Figure 1 and consists of cluster members and Cluster Heads. There are two types of transmission, namely,
Intracluster transmission

The source node transmits the packet to the Cluster Head within the same cluster, the distance between cluster member and the Cluster Head is small.

Intercluster transmission

The Cluster Head transmits the packet to the sink node or Cluster Head via the relay transmission. In this relay transmission cooperative sending and receiving nodes are used because the distance between the Intercluster transmission is large when compared to intra cluster transmission.

A MAC protocol IEEE 802.15.4, which is designed for low-rate Wireless Personal Area Networks (WPANs), has been adopted for interconnections between Wireless Sensor Nodes [2]. IEEE 802.15.4 ensures that data packets are sent from source node, which can detect the event and generate data packets to the Sink through intermediate node i.e. Cluster Heads, Cooperative nodes.

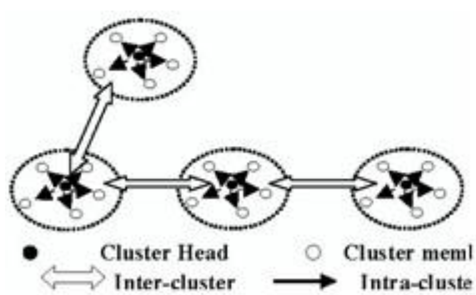
In random sleeping mechanisms, sensor nodes enter the sleeping mode randomly and independently from each other. Energy conservation is one of the most important issues in WSNs, since sensor nodes are usually powered by batteries. The radio transceiver is the most power consuming component in a sensor node.

A typical radio transceiver consists of four possible modes with different power consumption, such as

- Transmitting
- Receiving
- Listening and
- Sleeping

The first three modes are also called active / wakeup modes, in which more energy is consumed. Observing idle listening, the status that a sensor node turns on the radio to monitor wireless medium but do not receive any packets, wastes a lot of energy, some researchers propose medium access control (MAC) protocols to turn the radio into sleeping mode as long as possible to save energy for prolonging the network lifetime. However, the radio should be scheduled to be in wakeup mode periodically to monitor, send or receive data packets.

The MAC protocols that make the radio alternate between sleeping and wakeup modes are called the SLEEP and WAKEUP schedule protocols. For example, when two neighboring nodes are exchanging data, all two-hop neighbors of the two nodes are prohibited from doing so. Those prohibited nodes stay at receiving mode until the data exchanging finished, which causes an energy-wasting status called overhearing. The RTS / CTS scheme can be used to avoid overhearing as well as to solve the hidden terminal problem. But, the scheme's overhead is relatively large for WSNs since packets in WSNs are usually very small. Hence an Asynchronous Duty Cycle is proposed in this paper.



Cluster Head Cluster member Inter-cluster Intra-cluster transmission transmission

Figure 1 Typical clustered Wireless Sensor Networks

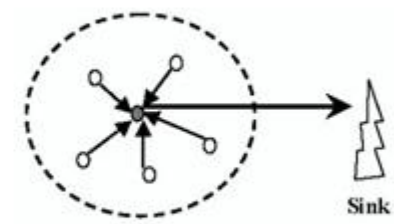
Adjustment MAC protocol provides low energy consumption, low transmission latency and high throughput in WSNs. Adjustment MAC protocol is an Asynchronous SLEEP and WAKEUP Procedure [3] which will not need to synchronize nodes timers, so the timer synchronization overhead is avoided. It also allows each node to set its own SLEEP and WAKEUP schedule independently. Simulation experiments for Asynchronous SLEEP and WAKEUP Procedure are performed and also the simulation results for both with and without Asynchronous SLEEP and WAKEUP Procedure are compared to show the advantages of Asynchronous SLEEP and WAKEUP Procedure.

II. CLUSTERING STRUCTURES IN WIRELESS SENSOR NETWORK

In a clustered Wireless Sensor Network, all members of the clusters are directly connected to the Cluster Heads (CHs). Sensor nodes in the same cluster can communicate directly with their CH. CH can transmit gathered information to the Sink as shown in Figure 2.

Each sensor node is assigned a unique ID number by the base station before it is deployed. Node ID number are saved in the Sink. A Cluster Head is a sensor node with better resources and may be used to collect and merge local traffic and send it to the base station. During the network operation, the Cluster Head is responsible for the integration of all cluster node data and transmitting the data to the sink.

The Cluster is composed of a Cluster Head and sensor node members. Each cluster has a unique cluster ID number. Cluster sensor nodes communicate with their Cluster Head directly, and there is no data exchange between sensor nodes. The Sink is typically a gateway to another network for data processing / storage center, or an access point for human interface and to collects the sensor readings.



Cluster Head Cluster

Figure 2 Clustering of Sensor Nodes

III. COOPERATIVE COMMUNICATION DESIGN

Cooperative communications is a way to select a relay node that will efficiently forward the packets in a cooperative way. Various cooperative schemes have been developed for high throughput and compared with the non cooperative scheme [4], [5], [6], [7]. The relay selective cooperative schemes have been used recently, where only higher potential nodes are chosen in the cooperative communication process.

Direct Transmission sensor nodes; transmit the data directly to the Sink / Cluster Head sensor node, as a result node that is far away from the sink would die first. Compared with the non cooperative scheme (direct transmission), the successful data transmission can be achieved by using relay cooperative transmission. However, a successful packet transmission in the relay cooperative transmission scheme involves transmitting node and the receiving node. In the energy-constrained Wireless Sensor Network, minimum energy consumption for the successful packet transmission between the source and the destination can be achieve by using proper design of cooperative transmission scheme.

IV. SYSTEM MODEL

Considering sensor networks where static sensor nodes are randomly located in a given region, the traffic in the network is light, and hence transmissions are collision free.

A sensor node is either in an active mode / asleep mode according to its sleep schedule. In the sleep mode, a node is turned off and no power is consumed. Every time, a node ***i*** goes into the sleep mode, it sleeps for a period ***Tslp*** of time before waking up. The sleep time of a node is fixed, but different nodes have different sleep times due to different traffic and battery distributions. A node wakes up and enters an active mode from time to time to see if it has any packets to transmit or if there are any other nodes attempting to transmit to it. An active period can be further categorized as an idle listening slot, a data transmission slot, or a data reception slot. In an idle listening slot, if the node neither transmits nor receives data packets within this active period. In this case, the active period consists of two parts,

- RF initialization
- Channel detection

An active period is said to be a data transmission slot if the node transmits a packet in this slot. Likewise, an active period is a data reception slot if the node receives a packet in this slot. A node ***i*** initializes its RF circuits immediately after it wakes up. Assuming that it takes a node ***Trf*** units of time and ***Erf*** amount of energy to initialize its RF circuits. If the node has data to transmit, it first listens to the channel for a period of amount of energy to initialize its RF circuits. If the node has packets to transmit, it first listens to the channel for a period of ***Tlis*** time to see if any of its neighbors are transmitting. Defining ***Tdet*** as the total time from when a node wakes up to when it goes to sleep again is depicted in Equation (1).

If the channel is idle for Tdet time, the node sends a Request to Send (RTS) preamble. If the target receiver is also in an active mode and receives the RTS preamble, it replies with a Clear to Send (CTS) packet. The transmitter will then send a data packet, which is acknowledged by an ACK packet from the receiver. Otherwise, if the receiver happens to be in a sleep mode, the transmitter will resend the RTS preamble after going to a power saving status for a short time***Tsav.***This process is repeated until the receiver wakes up and captures the RTS preamble. Throughout this paper, it is assumed that all packets, including preambles, are transmitted at a constant power level ***ptx.***

V. WORK FLOW FOR THE PROPOSED METHOD

Step 1: Initialize the Nodes
Step 2: Electing the Cluster Heads
Step 3: Transferring the message to Cluster Head from non
Cluster Head
Step 4: Cooperative node selection
Step 5: Request message send to neighbor Cluster Head to
select its cooperative its nodes
Step 6: Applying sleep and wakeup procedure to the sensor
nodes other than Cluster Head and cooperative nodes
Step 7: Transfer the message to sink via intermediate
Clusters

Considering Clustered Wireless Sensor Networks where static network and sensor nodes are located in a given region. Considering the traffic in the network to be light, transmissions are collision free. Electing highest energy node as the Cluster Head in each clusters, transferring the message to the Cluster Head form cluster members and considering, the Cluster Head is electing the next highest energy nodes as cooperative sending and cooperative receiving nodes in the same cluster. A request is sent to next Cluster Head to selects select its next highest energy nodes as cooperative sending and cooperative receiving nodes. Once the Cluster Head and Cooperative nodes are selected, apply sleep and wakeup procedure for the remaining nodes, i.e. other than Cluster Heads and cooperative sending and receiving nodes. Transfer the data to the sink form source Cluster Head and the data paths is via intermediate clusters.

VI. EXAMPLE FOR THE PROPOSED METHOD

As in Figure 3, thirty seven Nodes are deployed including Sink Node. The Nodes are placed in zigzag manner form bottom left to top right, there are six rows and each row contains six Nodes; 37th Node is the Sink Node and the Sink Node is active throughout the network lifetime. Considering Node1, Node 2, Node 3, Node 7, Node 8, Node 9, Node 13, Node 14, Node 15 as belonging to Cluster 1, and Node 4, Node 5, Node 6, Node 10, Node 11, Node 12, Node 16, Node 17, Node 18 as belonging to Cluster 2, and Node 19, Node 20, Node 21, Node 25, Node 26, Node 27, Node 31, Node 32, Node 33 as belonging to Cluster 3, and Node 22, Node 23, Node 24, Node 28, Node 29, Node 30 , Node 34, Node 35, Node 36 belong to Cluster 4. The scenario used here is all-toone environment where all Cluster periodically report data to a Sink. In this scenario, suppose Cluster 1 wants to transmit data to Sink i.e. Node 37 the possible routing is via Cluster 4; Node 8 is as Cluster Head in Cluster 1 because Node 8 holds the highest energy. Node 14 & Node 15 are selected as Cooperative sending and receiving nodes as they it hold the next highest energy. Data path from Cluster 1 to Sink is via intermediate Cluster 4, Cluster 4 chooses Cluster Head as Node 35, and Cooperative send and receiving nodes as Node 28 and Node 23. Data path for Cluster 2 is via Cluster 4 and similarly data path for Cluster 3 is via Cluster 4. Cluster 4 is at one hop distance to transmit the data packet to Sink Node, so there is no need to choose the Cooperative sending and receiving nodes.

VII. TRUETIME TOOLBOX

True Time (TT) is a MATLAB / Simulink based co simulation tool box developed by Lund University, Sweden [8]. It provides a simulation environment for network control and sensor network. The code functions for the tasks and the initialization commands may be written either as C++ functions or as Matlab M-files.

A. Installation

Add the following lines in the Matlab startup script. This will set all necessary paths to the TRUETIME kernel files.

```
setenv('TTKERNEL', 'Location')
addpath([getenv('TTKERNEL')])
addpath([getenv('TTKERNEL')
'/matlab'])
```

Starting Matlab and giving the command: **truetime,** the Matlab prompt will now open the TRUETIME block library as shown in Figure 4.

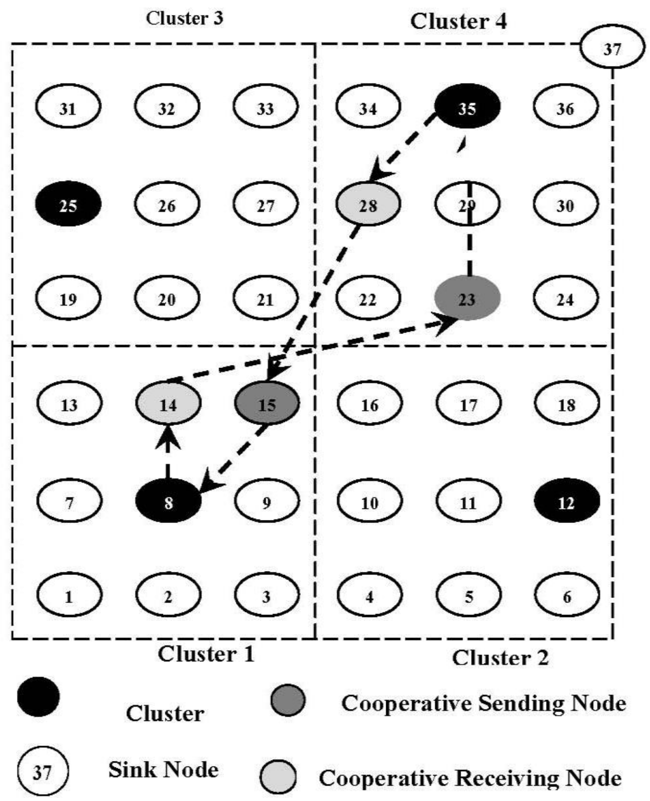


Figure 3 Example for the proposed method

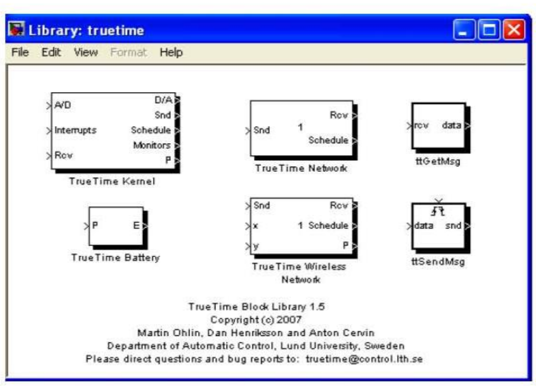


Figure 4 TRUETIME 1.5 block library

The network model uses Truetime wireless network model to realize, which is shown is Figure 6, where Rcv, x, y, and Snd, p ports are corresponding to node ports of the same label. The parameters of network are set through attribute window.

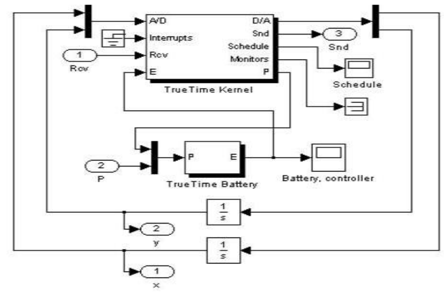


Figure 5 Individual node structure for a wireless sensor node

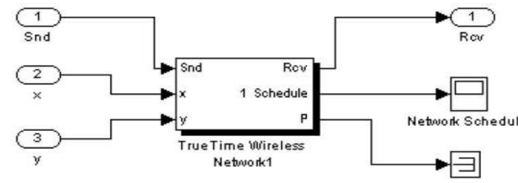
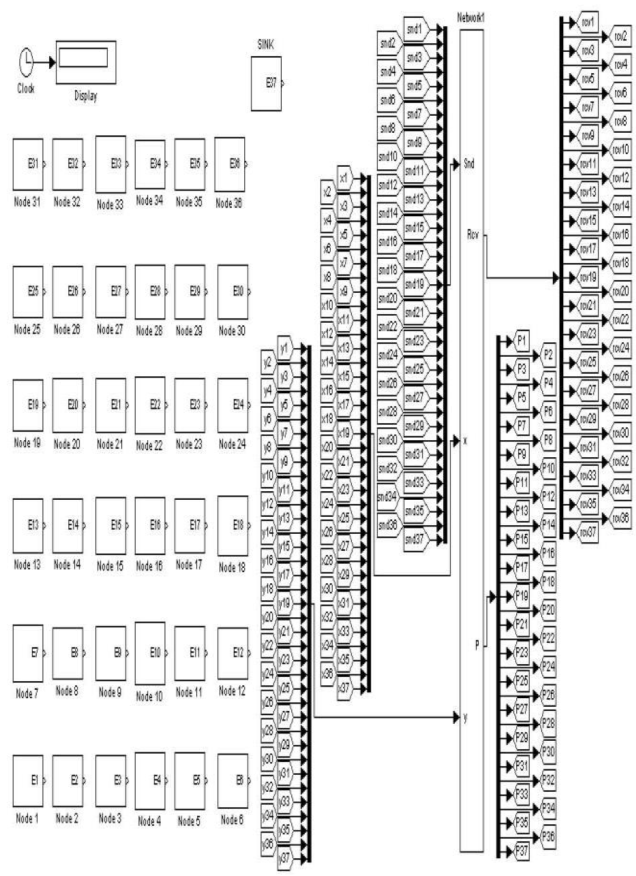


Figure 6 Internal structures for Wireless Sensor Network



The scenarios in Figure 7 are described below: simulation area is a square with 100*100 m^2, there is a a source node to send messages to the sink stations. Simulation runs in 802.15.4 environment, and the data rate is 250 0Kbits/s.

VIII. RESULTS AND DISCUSSION

In this paper the simulation is performed using MATLAB platform. Two types of Procedures have been analyzed i.e. with and without SLEEP and WAKEUP Procedure for the cooperative communication in a clustered Wireless Sensor Network. The power and energy consumption mode of Mica2mote and CC1000 transceiver, as depicted in Table have been used in simulating the wireelesss sensor nodes. All nodes have different battery capacity. The network life times obtained by two Procedures are compared. One scenario is all-to-one environment where all clusters transmit data to a sink.

Node 6 in Cluster 2 transmitting data to sink via intermediate Cluster 4				
Nod e No	**Initial Energy value for Wireless Sensor Node (Joules)**	**Energy remaining in the Node**		**Energy Saved value by applying Sleep & wakeup procedure (Joules)**
		By applying Sleep & wakeup procedure (Joules)	**By applying Without Sleep & wakeup Procedure (Joules)**	
1	4.088439	4.081798	4.04156	0.040238
2	4.905879	4.899238	4.859	0.040238
3	4.309949	4.303309	4.263	0.040309
4	0.419104	0.412464	0.37225	0.040214
5	1.68856	1.681919	1.64169	0.040229
6	1.180646	1.1687	1.1246	0.0441
7	1.589027	1.582386	1.54215	0.040236
8	4.922242	4.88709	4. 88709	0
9	2.741254	2.734614	2.69438	0.040234
10	3.746256	3.700544	3.700544	0
11	4.209259	3.347038	3.347038	0
12	0.834449	0.827808	0.78757	0.040238
13	4.515488	4.508847	4.46869	0.040157
14	0.525621	0.51898	0.47871	0.04027
15	3.725465	3.718825	3.67859	0.040235
16	3.64686	3.611708	3.611708	0
17	3.587348	3.580707	3.54047	0.040237
18	0.667159	0.660518	0.620291	0.040227
19	2.228945	2.222304	2.18207	0.040234
20	2.543936	2.537295	2.49706	0.040235
21	2.652451	2.645811	2.60558	0.040231
2 2	4.298585	4.296466	4.296466	0
23	3.388625	3.381984	3.34175	0.040234
24	4.029191	3.982106	3.982106	0
25	2.656214	2.649574	2.60934	0.040234
26	4.779479	4.744327	4.744327	0
27	0.333385	0.326744	0.28651	0.040234
28	2.70759	2.700949	2.66072	0.040229
29	1.408302	1.401661	1.36132	0.040341
30	2.404502	2.397861	2.35762	0.040241
31	3.424319	3.417678	3.3774	0.040278
32	1.041292	1.034651	0.99442	0.040231
33	3.040805	3.034164	2.99393	0.040234
34	1.630881	1.62424	1.58401	0.04023
35	4.404236	4.366469	4.366469	0
36	0.666973	0.660332	0.6201	0.040232

IX. CONCLUSION

The flexibility, cost and rapid deployment characteristics of Wireless Sensor Networks create many new and exciting areas of application for remote sensing. In the future, these wide areas of application will make sensor networks an integral part of our lives. However, realization of energy consumption in sensor networks is essential. A Clustered

Wireless Sensor Network with Cooperative design preserves lot of energy when compared to non cooperative communication design. To improve the energy consumption further in cooperative communication design of a clustered Wireless Sensor Network, an asynchronous sleep and wakeup procedure is introduced in this project. The concept of scheduling sleep and wakeup procedure is very effective. The proposed model proves that energy consumption is reduced to a great extent by using sleep and wakeup procedure.

X. REFERENCES

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