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Dynamic Signal Transmission in Wireless Sensor Network using Sensible Power Management

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ABSTRACT

The wireless sensor network usage has been increased to a greater extent nowadays. The usage of wireless sensor network is extended to a vast number of applications, such as health monitoring, pipeline structure alignment monitoring, weather monitoring, transportation management, Agriculture, manufacturing process, etc..,. The nodes which form the wireless sensor network are called as wireless sensor nodes. These nodes use limited battery resources for working and also it cannot be backed up by large power resources. Physical monitoring and changing of the batteries are not convenient at all times since the placement of these sensor nodes are not always accessible and the environment is also not suitable for humans for most of the cases. In such scenarios the usage of the limited power is an important factor in wireless sensor networks. In this paper, we proposed an SPM (Sensible power Management) algorithm to preserve the power by controlling the receiving and transmission of the signals to and fro from the nodes. The main aim of the algorithm is to analyze the need for transmission and the power needed for transmission and detect the false node, thereby preventing unwanted transmission. Identifying the need for transmission is a heavy computational process and our aim is to increase the life time of the nodes and also to reduce the computation time needed. This automatically leads to an increase in the life time of the wireless sensor nodes.

Keywords: dynamic transmission, wireless sensor network, wireless sensor nodes, power management

1. INTRODUCTION

Wireless sensor networks have been popular in the world for its low cost and availability and mainly due to its simple design structure. The sensors can be used to monitor the environment and sense the required data and transmit using a transmitter and receives the data from other node using a transceiver. However in the usage of the industrial needs the main problem in implementing the wireless sensor nodes is that they have to support long distance communication where multiple hops needed for routing and also the nodes are not in the line of sight always. In this situation, the data rate is to be high for the desired throughput which should be matched to that of the wired communication. But increasing the data rate alone doesn't increase the throughput. This is due to the high collision among nodes due to contention.

Previously all the research has been concentrating on the power consumption of the wireless sensor networks. But they have not achieved the required result due to some of the following reason. First, they have been using the simulators which are ideal. Second they do not concentrate on the multi-hop in the routing. Third they used a large power consumption h/w which does not match with the ideal real-time

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situation, and finally, they used to concentrate only on the power required to transmit and receiving whereas the power needed for sleeping state and listening state is omitted.

In this paper, we analyze the necessary improvements in the power transmission. At first, the (SPM) algorithm is proposed for the power management. Second the SPM is tested against various traffic situations and lastly the algorithm is implemented and concluded for the result. The experimental result suggests that the power gain of the SPM is not much when compares to static power transmission during outward traffic and SPM gains upper hand in inward traffic. And for overall traffic, the power gain is not significant. When the radio activity is reduced by half the SPM gains the upper hand by consuming 36% less power compared to static transmission. The result suggests that the SPM is bettered in the low power systems which use less radio activity.

The paper is organized into three categories section II-related works, Section–III-algorithm description and methodology Section–IV–Implementation.

2. RELATED WORKS

There have been many previous works based on the energy optimization, routing optimization for power adjustment. We have proposed an algorithm for power optimization based on the dynamic nature of the wireless sensor nodes. In LINT [1] the transmission is adjusted based on the degree of the neighbor nodes and their limit (Dmin to Dmax). The power setting is based on the difference between the current power setting and target power setting according to the neighbor needs. Another approach is given by LMA, LMN [2]. Using a single degree of the connected neighbor is used in LMA; single degree of average neighbor connected is used in LMN. In both of the presented methods, a static approach is used. DTPC [3] is another approach based on the connectivity based adjustment. It is build based on the RSSI fitness threshold of neighbors. In TPSO [4] the main concentration is on the EMI minimization. Nodes in TPSO are quantified based on anefficiency metric. Transmission power is adjusted gradually from a minimum setting and stabilized when a [Dmin, Dmax] limit is reached.

2.1. Link-Based

In [5] a series of experiments are performed to show gray correlation areas of MAC metrics, like RSSI and LQI, with Load Accepting Rate (LAR) and to pinpoint asymmetries in links. They use PCBL as a two-phase scheme of adjusting transmission power for individual links. The first phase is responsible for collecting statistics of various transmission powers for individual links and calculating the lowest transmission power required for reliability, for each neighbor. The second phase uses the correlated transmission power setting for each link to meet the LAR demands while blacklisting links that cannot maintain reliability and symmetry. Symmetry is indirectly assumed by LAR performance. Blacklisting is based on two thresholds. THLQ is a link or packet based threshold for LAR requirements while THBL is a blacklist threshold used to remove links that cannot be improved in the adjustment phase. In the end, each node maintains a list of reliable neighbors with a specific unicast transmission power and uses the highest power value from this list for broadcasting. Authors of [29] support correlation of MAC metrics like RSSI or LQI with LAR through a series of experiments. They present ATPC, a feedback based protocol that initially samples RSSI/LQI values with broadcast messages and verifies them with acknowledgments. Each node maintains a neighbor list with the minimum transmission power level required for high LAR (derived from instant RSSI/LQI values). The feedback mechanism involves transmission power adjustment that addresses any temporal impact on link quality using a least square approximation predictive model. In [6] ART is presented, a lightweight protocol that uses LAR to describe link quality. Its main functionality involves a) two sliding window thresholds for failure calculations with two correlated LAR values in order to set proper transmission power, b) three different states for link assessment (initial-steady-trial), c) A high contention flag to decide an increase or decrease of transmission power. ART acts like a mid-layer solution to existing protocols, creating LAR statistics by monitoring higher layer communications and acknowledgements. ODTPC is an on-demand approach that is introduced in [7, 8]. It works with a two-phase transmission scheme, where in the first phase neighbors are quantified with RSSI values and acknowledgements on maximum transmission power. In the second phase the transmission power fixes to the smallest value that ensures proper communication for each individual neighbor. The lightweight supplementary nature of ODTPC, allows it to be easily embedded into other protocols

3. SPM (SMART POWER MANAGEMENT)

The main concept of the SPM is to detect the false positive node (i.e.) the node which can be communicated from sender but not vice versa.

3.1. False Node Detection

Nodes in the network simply broadcast information autonomously without expecting the need for acknowledgements from other nodes. Problems occur when there is dynamic behavior and failures or increased or decreased the power of transmission during the working. For working of the nodes, the LAR (Load Accepting Rate) for the sender node and the receiver node inv_LAR is calculated. This reverse inv_LAR for node A is based on node B and this inv_LAR is used to estimate the false node in the networks.

We see that node A maintains information about node B {LARB, inv_LARB}, and node B maintains information about node A {LARA, inv_LARA}. The symmetric link is at best at {80%, 80%} from both no ends. At any instant, node B decides to reduce its transmission power enough to sever the symmetry of the link. Node A can deliver messages normally to node B, but node B cannot deliver messages to node A and thus cannot send LARA to node A. In the meantime LARB will start to slowly converge towards the actual behavior of node B. inv_LARB, on the other hand, cannot be updated by node A and will remain stale. Without any awareness of the lack of connectivity to node B, node A would still advertise symmetry to node B until LARB finally gets under a minimum threshold. But node B is able to receive messages from node A and keeps on maintaining symmetry in the link and continue to consider node A as a valid neighbor

We propose an effective solution to this problem in the form of a trust based mechanism:

1. A Trust value T to operate LAR with T [Tmin, Tmax]. T stacks per successful message, reduces per failed delivery.
2. A trust value inv.T to operate inv_LAR with T [Tmin, Tmax]. Inv. T accumulates per successful delivery of inv_LAR information, reduces on non-delivery.
3. A Trust threshold TTH = (Tmin+Tmax)/2
4. A link is symmetric and coherent (SAC) when both T > TTH and inv.T> TTH.

Following this scheme we see that as soon as node B can’t deliver messages the threshold limit falls below the TTH threshold and the link is not considered as viable, nor it is included in the broadcast messages of node A. But the Node B maintains higher TA for node A, in real there is no delivery for inv_LARA so the connection is not considered to be valid. But the link is trusted to deliver data or the intimation of lack of information, node A is considered forthe node B broadcast. We will be referring to the degree of SACs in a node as SACD, the nodes that contain an SACD less than the Dmin threshold as local SACD minimums, while the nodes that contain an SACD higher than the Dmax threshold as local SACD maximums.

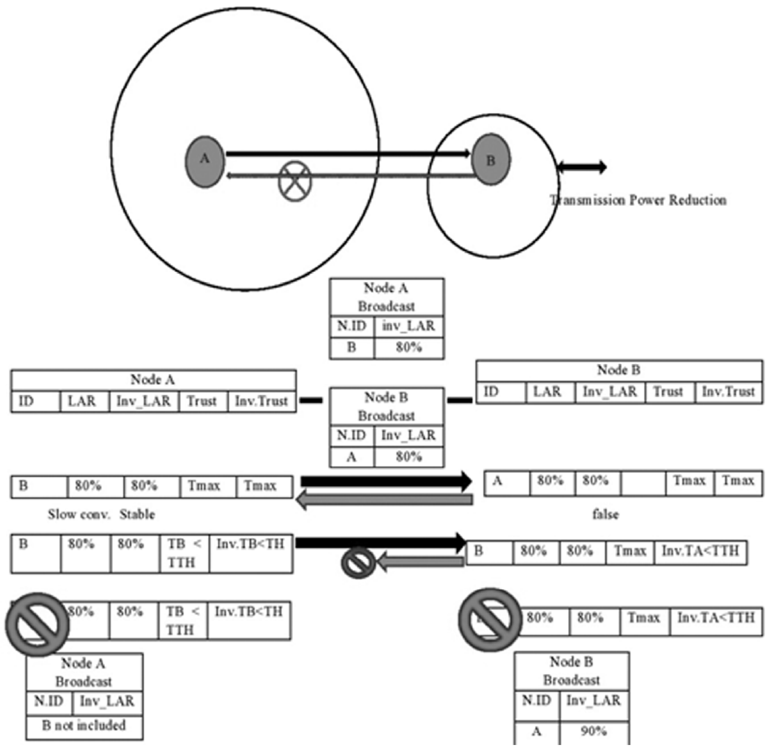

Figure 1: False Node B is detected due to mutual understanding due to TB < TTH and not included in the broadcast. Node A is not considered as neighbor due to inv_TA < TTH, but included in broadcast as valid

3.2. Power Aware transmission

An important change we made is to include upper and lower bounds [Dmin, Dmax] for the links delivered (like LINT and LMA/LMN) and not a single Dmin threshold (like DTPC) for two reasons. First it is hardtop maintain the exact degree for the nodes. In the case of our iSense nodes, the variation of the two transmission power range is too large that this could vary the behavior between two power ranges. The low value will never be greater than Dmin and high value will always high then Dmin. Secondly, both degree thresholds in [Dmin, Dmax] are based on user input and constitute what we consider a node incentive towards a load balanced topology. Nodes in dense areas will strive to reduce their transmission power and nodes in sparse areas will strive to increase their transmission power. Protocols that utilize the delivered links, will have less chances of dealing with connectivity local minimums and interference local maximums [7]. Unlike DTPC but similarly to TPSO we choose to start the convergence process, with the minimum transmission power setting for all nodes. In the case of dense deployments, links that require the minimum transmission power, are going to be created first and antagonize for a position in the limited [Dmin, Dmax] space. More precisely it’s the Dmax upper bound that creates the antagonism of inclusion for links during the monitoring phase. Links that require less transmission power create less interference and are likely to subject fewer nodes to that interference.

Another feature of SACD-ATP is the ability to mitigate the effects of node exclusion in converged neighborhoods. Since we start with the minimum transmission power on all nodes, we always favor the shortest available links. This could initiate problems in terms of the topology specification and also tends to exclude the nodes. For example, there may disconnect nodes in a network and these are the nodes which tends to increase their transmission power range in order to discover the other nodes in the network using their beacon signal. If the other node responded for the beacon and if the responded nodes has low transmission setting then automatically they will be excluded. And these nodes are always being excluded from participation. An easy way to mitigate this effect is for all nodes to advertise their SACD in their beacons. A receiving node monitors the information and updates the knowledge before transmitting the beacon and the links maintained by a node are sorted by their advertised SACD. Priory is given to the first

Dmin number of links with the least SAC Degree. Power needed for transmission can be increased to connect the most needed nodes. With this technique, the priority of maintaining the shortest links can be overridden by the presence of excluded nodes or less connected nodes [9].

4. IMPLEMENTATION

For experimental purpose we have used virtual machine image. The Virtual machine is a pre-configured development environment for WSN and it has Shawn simulator, test bed client script programs test bed runtime for personal desktop test bed. The testing environment we used Shawn simulator with 30 x 30 m2area and the output of the experiment will be 1) transmission power range Fig.3 2) LAR for packets Fig. 2 3) false node detection Figure1.

4.1. LINT/LMA/LMN Performance

Algorithm LINT:

(Algorithm for node *u*)

kd is the desired number of neighbors

*k*min and *k*max are the low and high thresholds, centered around *kd*

1. Initialization

Set the transmit power level to the initial value

2. Setting the power level

Repeat until termination

Estimate the number of neighbors, *nu*

If *nu* < *k*min then

IncrTxPower()

Otherwise if *nu* > *k*max then *DecrTxPower()*

Set timer *TCFreq()*

Wait until the timer is expired

The LINT protocol is probably intended mobile network through TC protocol. It maintains a threshold limit for high and low levels which is based on the number of neighbor nodes. It tries to keep the neighbor level well within the limit. The neighbors are checked at frequent intervals if the transmitting power is low than the threshold then the transmitting power gets increased else vice versa. If the limit is within the acceptable limit then the transmitting limit is left unchanged. In LINT it describes a system to adjust the transmit power, as a function of the current power level and of the actual and desired number of neighbors. An important aspect that is not considered is how to set the value of the desired number of neighbors. An important feature of LINT is the mechanism used to estimate the number of neighbors within a node's transmitting range. In LINT, a node uses locally available information provided by the routing protocol to estimate the neighbor number. In fact, routing protocols usually have a neighbor discovery mechanism, which is used to monitor the status of the links to neighbor nodes. In LINT description, it is assumed that the routing protocol returns information on bidirectional links only.

4.2. SMP performance

The implementation of the SMP is based on the Wiselib's topology control concept. The SMP acts as an interface between the radio and the layer protocols. It is done in two processes. The first phase consists of the following;

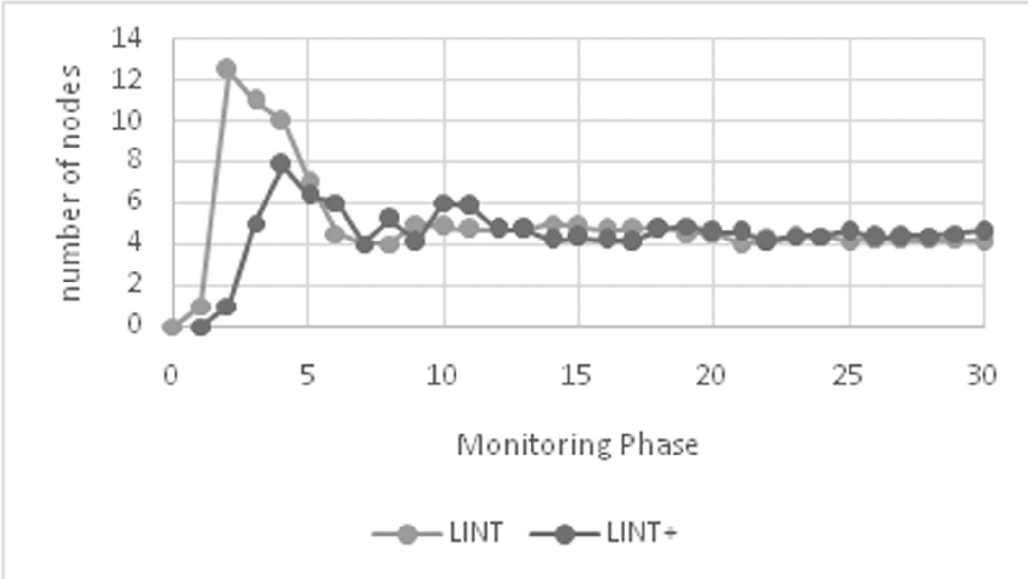

Figure 2: Average Degree for LINT/LINT+

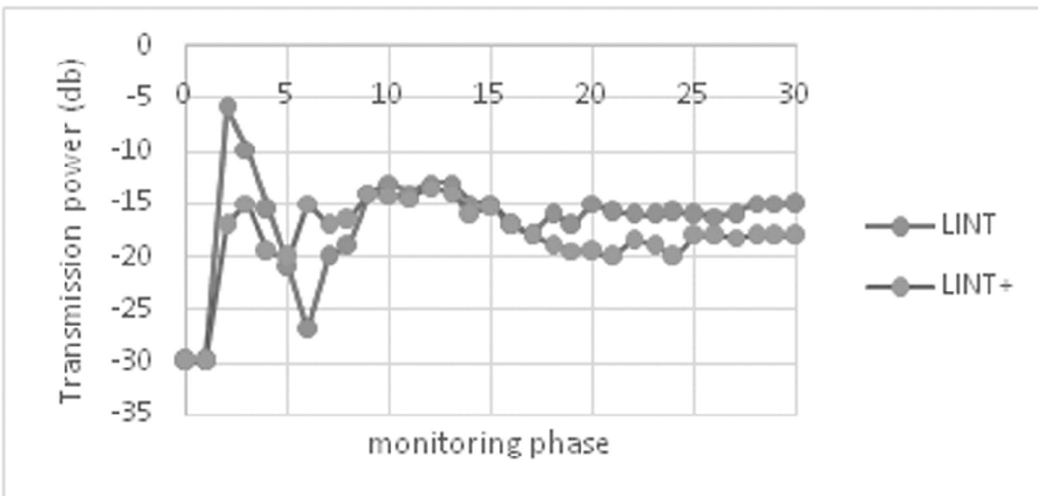

Figure 3: Average Transmission Power

i) Beaconing and broadcasting

ii) Updating and maintaining of the neighbor nodes

iii) Maintaining threshold for filtering

iv) Updating current LAR values

v) Maintain dynamic threshold

The output of the first phase is given in Fig. 4. The second process consists of maintenance of the power needed for transmission. Based on the quality of the links and the number of neighbor nodes the transmission power gets increased or decreased or no changes is made Fig. 5. This process is an background process which keeps on monitoring the entire nodes.

1) Individualistic TX Power control

If (SACD < D min) then

Increase transmission power

Else if (SACD > D max) then

Decrease transmission power

End if

2) Balanced TxPower control

1. if (SACD < D min) or (local SACD mins > 0) then
2: increase transmission power
3: else if (SACD > D max) and (local SACD mins = 0) then
4: decrease transmission power
5: end if

The advantage of using SMP is

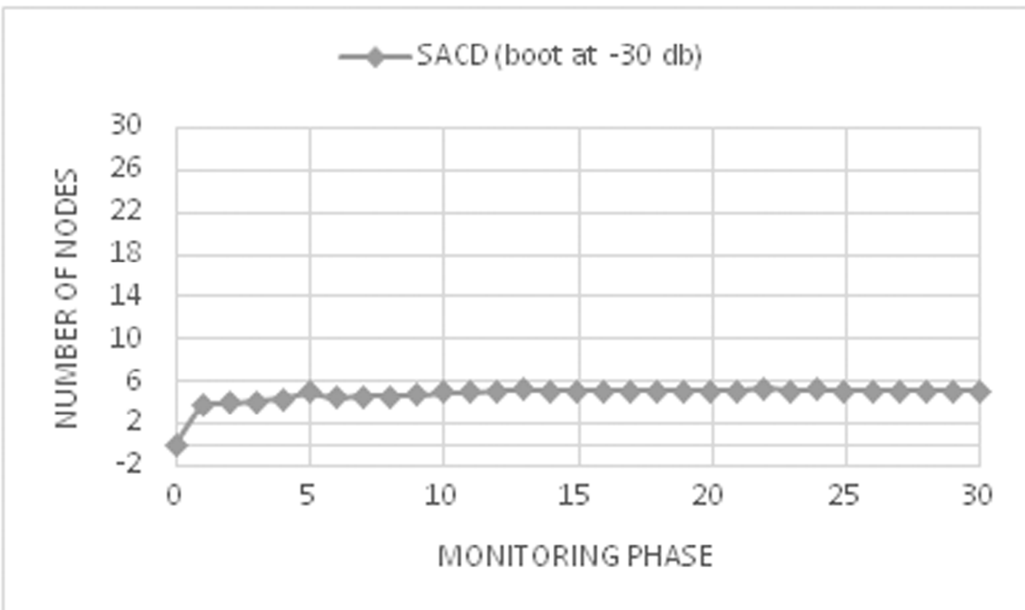

Figure 4: Average SACD for 30 db settings

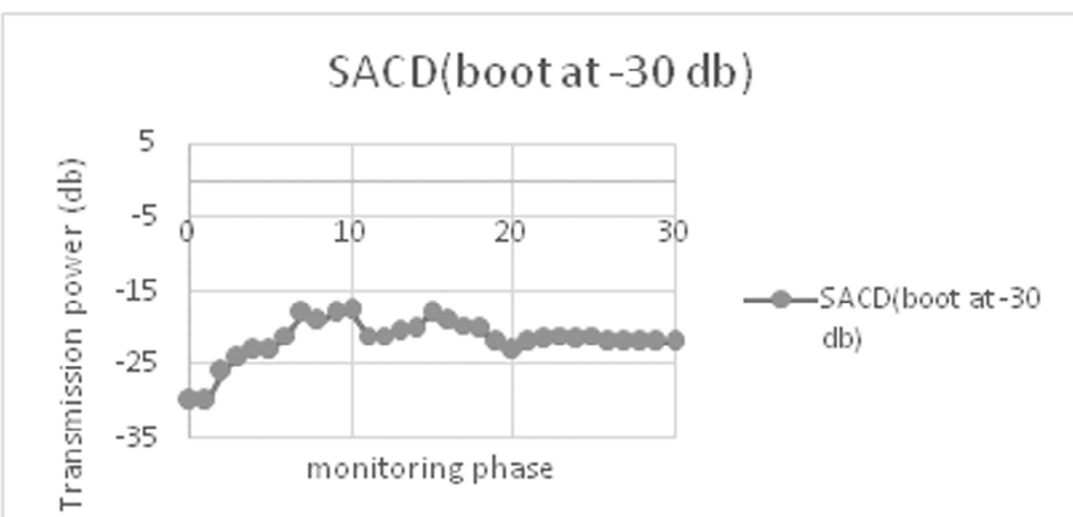

Figure 5: Average transmission power for 30db setting

- Simplicity in communication with minimum arrangement in nodes.
- Fully distributed and feedback based operation, with less knowledge for the nodes for information and using single type of broadcast message.
- No need for link performance assumptions like RSSI/LQI correlation to LAR.
- Enforced symmetry in terms of communication links.
- Control in communication using node level transmission control.
- Delivery an abstraction of the real network to be used by other protocols or applications based on user requirements.

5. CONCLUSION

In this paper we have proposed a solution for two problems false node detection and transmission power control in wireless sensor nodes. Using these approaches the nodes will be able to detect false nodes in the network and thereby avoiding the need to establish the connection between unwanted nodes or unreachable nodes. And using the second approach the power wastage is controlled by analyzing the receiving node strength and weakness before establishing the connection. If the node is located nearby the master node the power used for communication is lessen and if it is located at a far-off distance the transmission power is increased. Therefore the node which normally gets excluded is included in communication. Based on the result we can conclude that the SAC based SPM is better in power management and also in LAR for packets. The concept can be improvised even further and the power management can be reduced and the nodes can be tried to be auto stabilized.

6. ACKNOWLEDGEMENT

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