

Mobility Prediction for Power Efficient Communication in Mobile Wireless Sensor Networks

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ABSTRACT

Mobility should be effectively handled in Mobile Wireless Sensor Networks (MWSN) with respect to all the layers of the protocol stack. In this paper, designing a Mobility Prediction Technique for Power Efficient Communication in MWSN is proposed. In this technique, after predicting the mobility, most stable node is selected by the mobile node, through which data will be sent to the sink. Each node maintains a link status history so that link quality can be measured for each node during the mobility. Whenever a valid frame is received by the node from its neighbor, the time of each node and the Received Signal Strength Indicator (RSSI) is included in this status history. Based on the predicted link quality, the optimum set of data rate and power level is selected. The mobile node selects the relay node by considering the residual energy and MAC overhead. The simulation result show that the energy consumption and delay are reduced also the packet delivery ration has been improved by the proposed technique.

1. INTRODUCTION

1.1. Mobile Wireless Sensor Networks

The Wireless Sensor Network (WSN) includes large number of small, in-expensive and low power components which are able to process data and has the ability of sensing. The sensors in Mobile Wireless Sensor Networks (MWSN) have the features of mobility. MWSN includes the applications such as environmental monitoring, home security, biological detection, battlefield surveillance, smart spaces, inventory tracking, etc [1].

In future, the mobile devices create a new form of network with mobile sensors, as the sensors are smaller in size and they are in-expensive. But most of the existing studies on WSN assume only static sensors [2].

1.2. Energy Efficient MAC Protocols for Mobile WSN

Achieving energy efficiency is the most important and challenging task in design of WSN. Hence recent works on Medium Access Control (MAC) protocols mainly concentrated on energy efficiency rather than other metrics such as delay and bandwidth utilization [1]. Most of the existing MAC protocols on WSN may not be suitable for MWSN [2].

A mobile aware MAC protocol is the MS-MAC protocol, which is based on S-MAC which handles mobility by passing mobility information on messages. The lower connection time is formed by the mobile nodes which run in the synchronization period of S-MAC such that the mobile nodes in this protocol have active zones around them.

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Similar to TRAMA, the Mobility-aware protocol (MMAC) is also a scheduling based protocol for static networks. In MMAC, the mobility patterns are made adaptable to the protocol by introducing a mobility-adaptive frame time. To predict the future position of nodes, a localization service is used by the protocol. While wrong prediction in this protocol, the sensitivity is not known [3].

1.3. Problem Identification and Solution

From the literature review, the following issues are identified in existing works:

Unfortunately, the existing protocols are not suitable for the delay-sensitive wireless sensor networks, as the delay is ignored in them [7]. But none of the works considered the issue of link stability and channel condition while designing the MAC and routing protocols.

Hence our objective is to design efficient mobility aware MAC and routing protocols which address the issues of delay, link stability along with energy efficiency.

Followed by the above objectives, a mobile access protocol called MoX-MAC [7] has been proposed. In MoX-MAC, the major assumption is that the data should be forwarded by the mobile nodes to the static nodes. The static nodes have the responsibility of routing this data to the destination. In this process, the mobile nodes can be the potential transmitters as it waits for a random time before sending the data to the static node. The random time is often said to be backoff. However there occurs failure in the links due to the nodal movement. It assumes the presence of a static node which may not be possible. Moreover, it does not predict the node movement.

In [6], each node selects a set of transmission rate and power levels to schedule a job. For a pair of machines, for each selectable power level and for each selectable transmission data rate, an interference matrix can be associated. Once again it fails to consider the channel error and mobility issues of the machines.

2. RELATED WORKS

Junzhao Du et al [4] have proposed a method which gathers the global data called In-network communication cost, to optimize the energy consumption. In this method, the lifetime of the network is prolonged by eliminating the energy bottleneck. Within a given delay bound, the network wide data is widely collected by the Mobile Element efficiently. On a tree-shaped network, the trajectory planning for both Mobile Relay and Mobile Sink are considered. In Mobile Relay, RP-MR algorithm is proposed for the following approaches: 1) to collect global sensory data, the optimal Rendezvous Point (RPs) 2) to gather the cached data from RPs and to upload them to a fixed point (destination), the optimal data collection trajectory for further processing. In Mobile Sink, the sensory can be processed by the Mobile Element on its motion.

Xing Zhang et al [5] have built a secure tree structure route for mobility scenarios. It includes only a resource-constrained sink node in the large-sized wireless sensor networks. The mobile nodes are able to adapt the network topology changes by moving the sink node and by reconstructing the nodes. Thus the mobile nodes can rejoin the network securely.

Yosef Alayev et al [6] have studied a data dissemination scenario. In data dissemination, the data items are transmitted to mobile clients through one of the stationary data Access Points (APs). Along the stationary data Access Points (APs) the client passes by en route to their destinations. Assigning a job (the download by the client) to a machine (the AP) is similar to the sequences of the consecutive timeslots of an AP. During the time window of the client's range, this sequence of consecutive timeslots is dedicated by the scheduler to download a data item to a client. For each assignment, a transmission rate is chosen which is used to set a machine's speed along with the subtler effects formed. The transmission range of the APs is tuned to control its transmission power. Thus, the AP ensures that no interference occurs with the neighboring APs' transmission. The problem in this method is the generalization of an already NP-

hard parallel-machine scheduling problem. In this problem, the job's release times and deadlines are depending on the assigned machine.

Papa Dame Ba et al [7] have proposed a mobile access solution called MoX-MAC protocol. It is based on the reference protocol namely X-MAC protocol. To enable the mitigation of energy consumption of mobile sensor nodes, various mechanisms are employed in this protocol. Furthermore, they extended their former work by evaluating the lifetime of static nodes with respect to MoX-MAC protocol; as well determine the degree of depletion of static nodes due to the presence of mobile nodes.

Rongbo Zhu et al [8] have proposed an energy efficient and energy-aware Distributed Intelligent Data Gathering Algorithm (DIDGA). This algorithm has two phases namely cluster formation phase and path formation phase. In cluster formation phase, to ensure the coverage efficiency in WSN, a localized and distributed Minimum Connected Dominating Set (MCDS) is constructed based on Maximal Independent Sets (MIS). To enhance the network lifetime, a node is chosen as a cluster head based on the high residual power. In path formation phase, a Path Formation Optimized Algorithm (PFOA) is utilized. The data gathering path is planned by using the cluster head relay mechanism.

3. PROPOSED SOLUTION

3.1. Overview

We propose to design Energy Efficient Mobility Aware MAC Protocol for Mobile WSN. After the mobile nodes in MoX-MAC [7] send their data to static nodes, a link status history [2] is maintained in each node. The node movement in each node which causes link quality issue is addressed in this protocol. Whenever a valid frame is received by the node from its neighbor, the time of each node and the Received Signal Strength Indicator (RSSI) is included in the status history. As per MoX-MAC, the mobile node selects the most stable node as the relay node by predicting the mobility and send data to the sink through this node. If the link quality is lower than a threshold TL, the corresponding transmission can be blocked. The optimum set of data rate and power level [6] is then selected based on the predicted link quality. The projected error rate is the function of predicted RSSI value which is used to determine the threshold value of the link quality. The relay node selection is then done based on residual energy and MAC overhead.

3.2. Link quality Estimation

M-MAC maintains a table called RSSI history table, which includes the time and the value of the Received Signal Strength Indicator. Thus, the link status is maintained in M-MAC. M-MAC monitors the received signal strength from the periodic SYNC packets, by which the link quality and node mobility is speculated.

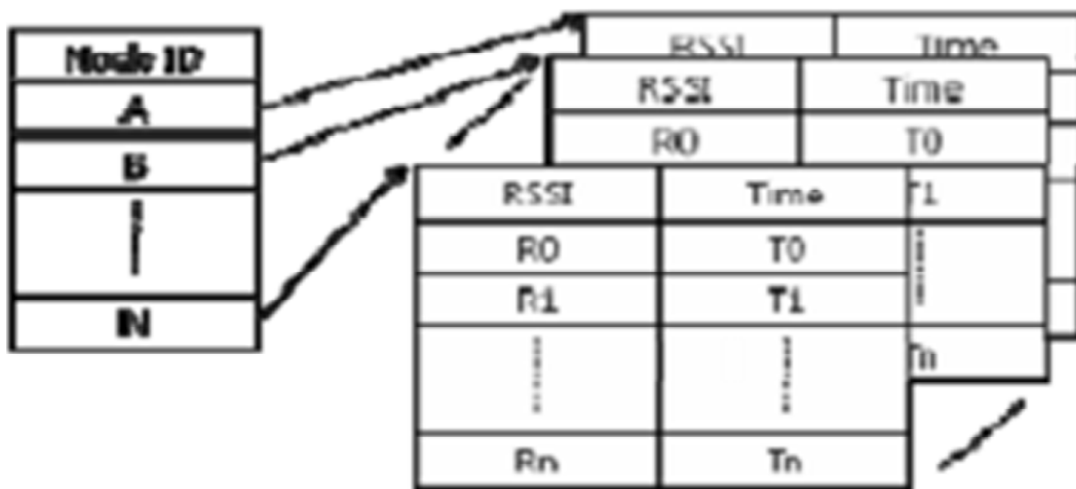


Figure 1: RSSI history table

RSSI is inversely proportional to the square of the distance between the sender and the receiver. The value of RSSI is the function of distance and the transmission power. The RSSI can be represented as follows,

$$P_{dr} = (P_t * G_t * G_r * h_t^2 * h_r^2) / d^4 * L \quad (1)$$

where P_{dr} – power received at distance d ,
 P_t – transmitted signal power,
 G_t – transmitter gain,
 h_t – transmitter antenna height,
 h_r – receiver antenna height,
 d – distance from the transmitter,
 L – path loss.

The examination of the predefined threshold value of link quality is used to predict the node mobility. When the link quality change is greater than this threshold value, the node is considered as moving.

The last time at which the node is static and the first time at which the node is mobile, are measured and the average is taken. From this average, the mobile node's departure time is estimated.

Consequently, the mobile node's speed can be calculated by applying the RSSI values recorded. This calculation has the prediction accuracy. This accuracy depends on the frequency of RSSI measurement and the time interval between the measurement and the prediction. The prediction accuracy will fail if there is no traffic for a long period of time.

3.2.1. Transmission control for a mobile link

M-MAC uses a dropping scheme to avoid unnecessary retransmission over a low quality link.

The projected error rate is used to determine the threshold value TL of the link quality. It is the function of the predicted RSSI. The Signal to Noise Ratio (SNR) is the linear function of RSSI, which is inversely

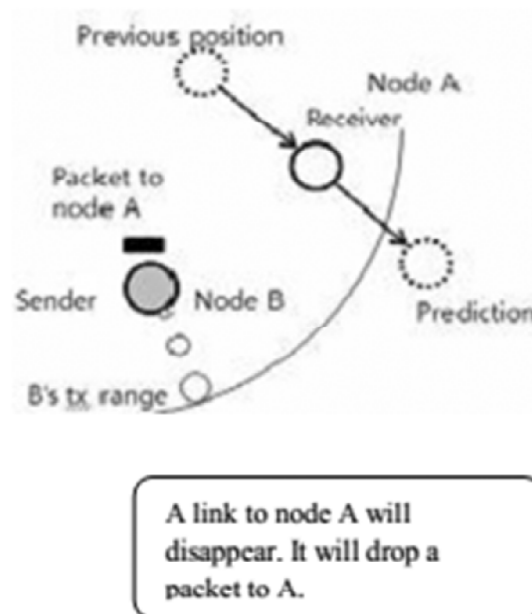


Figure 2: Dropping scheme

proportional to the error rate. The overhead of frame retransmission and the projected error rate can be calculated based on RSSI value. The dropping of packet will be occurred if the overhead is greater than the threshold. Consequently, the transmission will be blocked in the case of lower link quality when compared to the threshold TL.

3.3. Relay Node Selection

This relay node selection should minimize the energy consumption and MAC overhead, thereby increasing the lifetime of the networks. Hence the Relay Nodes (RN) is selected based on the MAC overhead and residual energy of the stable nodes.

3.3.1. Estimation of MAC Overhead

The MAC overhead is acquired by handshake signaling, Frame Transmission Time (FTT) and frame retransmissions due to transmission failure. The Frame Transmission Time (FTT) is defined as the period of time from which a frame is sent by S to the frame received by D. Thus, the detailed statement of the preceding problem is addressed by deriving the average MAC overhead including FTT and retransmission. It is denoted as E [Overhead] as follows [10]:

$$\text{Avg(overhead)} = \sum_{i=0}^{m=0} [(t_{\text{slot}} * \sum_{j=0}^i E[CW_j]) + (i + 1) * FTT](1 - p)p^i + [t_{\text{slot}} * \sum_{j=0}^m E[CW_j] + (m + 1) * FTT]p^m \quad (2)$$

Where, m – Maximum retry counter

t_{slot} – Time duration of a slot

CW_j – Contention window in retransmission stage

p – Transmission Failure probability of a station

$E[CW_j] = 1/2 CW_j$

FTT – Frame transmission time

3.3.2. Estimation of Residual Energy

After performing one data communication, the Residual Energy (RE) of each node N_i is calculated as follows [17],

$$\text{RE} = E_i - (E_{\text{tx}} + E_{\text{rx}}) \quad (3)$$

where E_i is the initial energy of the node,

E_{tx} is the energy utilized at the time of transmission of data and

E_{rx} is the energy utilized at the time of reception of data

3.3.3. Algorithm for RN selection

For each intermediate node N_i

If $\text{Avg}_i(\text{overhead}) = \text{Minimum}(\text{Avg}_i(\text{overhead}))$ and $\text{RE}_i = \text{Minimum}(\text{RE})$

Then select N_i as relay node

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Else
Ni will not be selected as relay node
End if

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4. SIMULATION RESULTS

4.1. Simulation Parameters

We use NS-2 [12] to simulate our proposed Mobility Prediction for Power Efficient Communication (MPPEC) scheme. In this simulation, within the 500 meter x 500 meter square region, 100 nodes are randomly deployed with nodes moving at varying speeds from 2m/s to 10m/s. the Constant Bit Rate (CBR) is the simulated traffic.

Table 1 is the summarization of our simulation settings and parameters.

Table 1
Simulation parameters

No. of Nodes	100
Area	500 × 500
Simulation Time	50 sec
Traffic Source	CBR
Speed of node	2, 4, 6, 8 and 10m/s
Propagation	TwoRayGround
Antenna	OmniAntenna
Initial Energy	7.1
Transmission Power	0.660
Receiving Power	0.395

4.2. Performance Metrics

By evaluating the performance metric, we compare the MPPEC scheme with the MoX-MAC protocol [8]. The performance metrics includes the packet delivery ratio, end-to-end delay, average packet drop and average energy consumption. The results are presented in the next section.

4.3. Results & Analysis

The speed of the mobile node is varied as 2,4,6,8 and 10m/s

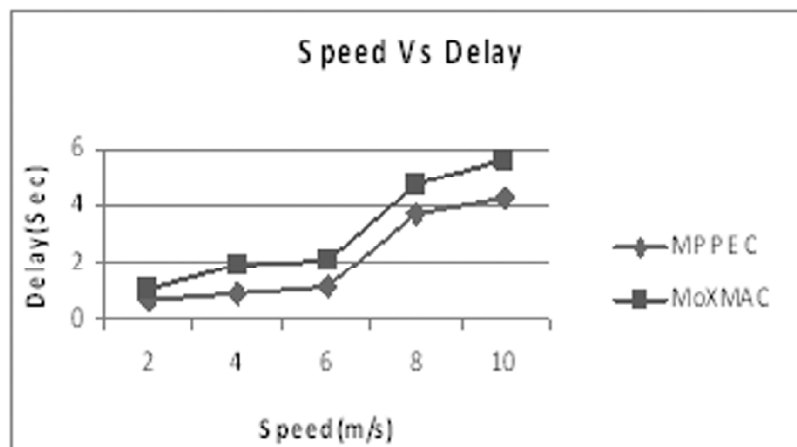


Figure 3: Speed Vs Delay



Figure 4: Speed Vs Delivery Ratio

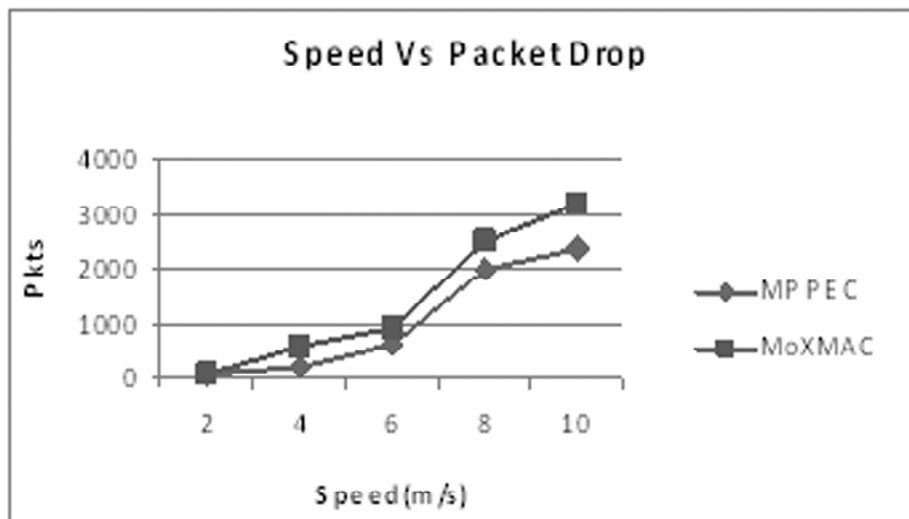


Figure 5: Speed Vs Drop

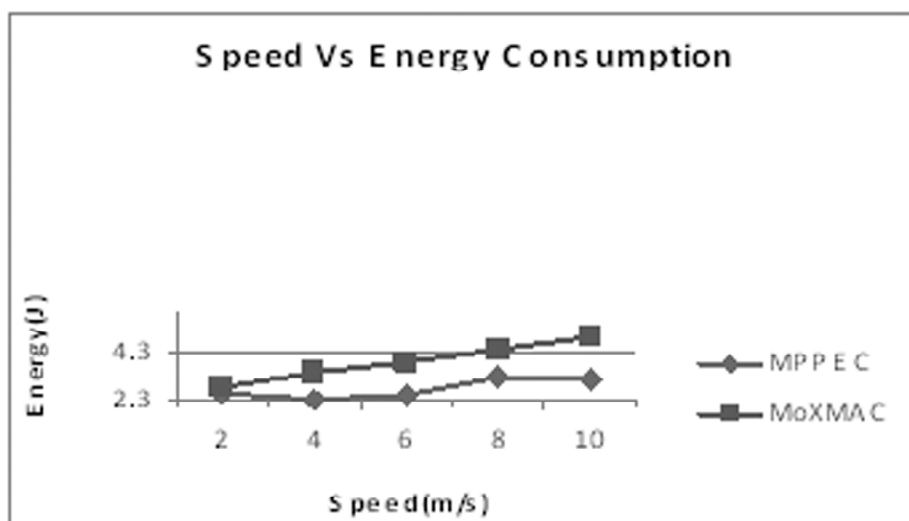


Figure 6: Speed Vs Energy Consumption

Figures 3 to 6 demonstrates the MPPEC and MoX-MAC protocols whose results of delay, packet delivery ratio, packet drop and energy consumption by varying the speed from 2m/s to 10 m/s. The

performance comparison of these protocol states that the MPPEC performs well than MoX-MAC protocol by 36% in terms of delay, 15% in terms of delivery ratio, 26% in terms of packet drop and 27% in terms of energy consumption.

5. CONCLUSION

In this paper, a Mobility Prediction Technique for Power Efficient Communication in MWSN is proposed. The MoX-MAC protocol is enhanced such that the mobile node selects the most stable node by predicting the mobility and send data to the sink through this node. For this, the node movement of the node causes the link quality issue; this is addressed by using the link status history maintained at each node. The optimum set of data rate and power level is then selected based on the predicted link quality. The mobile node selects the suitable relay nodes with highest residual energy and lowest MAC overhead. By the simulation results, we have shown that the proposed technique reduces the energy consumption and delay and it improves the packet delivery ratio.

REFERENCES

- [1] Chuan-Ming Liu and Chuan-Hsiu Lee, "Distributed Algorithms for Energy-Efficient Cluster-head Election in Wireless Mobile Sensor Networks", Conference on Wireless Networks (ICWN'05), pp. 405-411, 2005.
- [2] Lynn Choi, Sang Hoon Lee and Hyohyun Cho, "M-MAC: Mobility-Based Link Management Protocol for Mobile Sensor Networks", IEEE Software Technologies for future dependable Distributed Systems, pp. 210-214, 2009.
- [3] Arshad Jhumka and Sandeep Kulkarni, "On the Design of Mobility-Tolerant TDMA-Based Media Access Control (MAC) Protocol for Mobile Sensor Networks", 4th International Conference, ICDCIT, pp. 42-53, 2007.
- [4] Junzhao Du, Hui Liu, Longfei Shangguan, Luo Mai, Kai Wang and Shucong Li, "Rendezvous Data Collection Using a Mobile Element in Heterogeneous Sensor Networks", IEEE International Journal Of Distributed Sensor Networks, 2012.
- [5] Xing Zhang, Jingsha He and Qian Wei, "Energy-Efficient Routing for Mobility Scenarios in Wireless Sensor Networks" Proceedings of the third International Symposium on Electronic Commerce and Security Workshops (ISECS'10), pp. 080-083, 2010.
- [6] Yosef Alayev, Fangfei Chen, Yun Hou, Matthew P. Johnson, Amotz Bar-Noy, Thomas F. La Porta and Kin K. Leung, "Throughput Maximization in Mobile WSN Scheduling with Power Control and Rate Selection", IEEE Transaction on Wireless Communications, Vol. 13, No-7, 2014.
- [7] Papa Dame Ba, Ibrahima Niang and Bamba Gueye, "An optimized and power savings protocol for mobility energy-aware in wireless sensor networks", Telecommunications Systems, ISSN 1018-4864, 2013.
- [8] Rongbo Zhu, Yingying Qin, and Jiangqing Wang, "Energy-Aware Distributed Intelligent Data Gathering Algorithm in Wireless Sensor Networks", International Journal of Distributed Sensor Networks, 2011.
- [9] S. A. Hameed, E. M. Shaaban, H. M. Faheem and M. S. Ghoniemy, "Mobility-Aware MAC Protocol for Delay-Sensitive Wireless Sensor Networks", IEEE 2009
- [10] Bin Cao, Gang Feng, Yun Li, and Chonggang Wang, "Cooperative Media Access Control with Optimal Relay Selection in Error-Prone Wireless Networks," IEEE Transactions On Vehicular Technology, Vol. 63, No. 1, 2014
- [11] Vinh TRAN QUANG and Takumi MIYOSHI, "Adaptive Routing Protocol with Energy efficient and event clustering for wireless sensor networks", IEICE transactions, Vol E 91-B, No 9, 2008.
- [12] Network Simulator: <http://www.isi.edu/nsnam/ns>