ISSN 2278-3083

International Journal of Science and Applied Information Technology (IJSAIT), Vol. 3 , No.3, Pages : 28 - 31 (2014)
Special Issue of ICCET 2014 - Held during July 07, 2014 in Hotel Sandesh The Prince, Mysore, India

Adaptive Multipath Data Transfer in Multimedia Wireless Sensor Networks

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Abstract : Wireless Multimedia Sensor Networks (WMSNs) consist of nodes that are capable of transmitting event features in the form of multimedia such as audio, image and video data. Two of the important considerations in the design of efficient WMSNs are energy conservation and error free communication. Energy optimization directly leads to increased lifetime of a WMSN and reduction of packet drop rate relates to effective communication. An algorithm called MPDT proposed in [1] provides simultaneous multiple paths for delivering of data from the source node to the destination (sink) node. MPDT achieves longer network lifetime by distributing the communication load among nodes along multiple parallel paths.

In this paper, we consider an improvement over the MPDT by adaptively changing the number of multiple paths to minimize packet loss on one hand and to increase the network lifetime on the other. The advantage of the improved adaptive algorithm is brought out by showing simulation results obtained by using Qualnet network simulator and a supplementary C++ program. The results show that the use of the adaptive algorithm can improve the performance of a WMSN by balancing between network lifetime and packet drop rate.

Keywords: WSN, Energy Aware Routing, Multipath Routing

INTRODUCTION

Wireless Multimedia Sensor Networks (WMSNs) are a special class of sensor networks with nodes equipped with cameras, microphones, and other sensors for producing multimedia content. WMSNs enable new applications involving large-scale networks of small devices capable of generating information from the physical environment, performing simple processing of the generated data and transmitting it to remote locations.

In general, many applications of WMSNs have low bandwidth requirements, and are usually delay tolerant. Availability of low-cost hardware such as CMOS cameras and microphones has made WMSNs practically feasible. However, for effective application of WMSNs, several practical problems need to be addressed. Design of a data transfer protocol that can be immune to errors in communication that minimizes the energy consumption of the nodes, and assures multimedia consistency is still a challenging research problem. One of the approaches to improve lifetime of a WMSN is the use of multiple data paths from a source node to the destination (sink) node as described in [1]. The Multi-Path Data Transfer (MPDT) proposed in this work achieves improved network lifetime by distributing data communication load among nodes along multiple paths. With this as the background, we present a further improvement to the MPDT protocol in this paper. The proposed improvement involves adaptively changing the number of paths to transmit data to the sink node based on periodic assessment of the packet drop rate. The following sections give more details of the adaptive MPDT protocol.

RELATED WORK

Nasser et. al have explored the possibility of using multiple paths for data communication in WMSNs. A Secure and Energy- Efficient Multipath routing protocol (SEEM) is reported by them in [2]. The SEEM protocol uses multi-paths alternately as the path for communicating between two nodes and thus extends the lifetime of the network. The protocol is very resistive to some specific attacks that have the character of pulling all traffic through the malicious nodes by advertising an attractive route to the destination. In this algorithm the data is not transmitted simultaneously, but transmitted alternately.

Felemban, et. al have proposed a multipath multi-speed protocol for QoS guarantee of dependability and timeliness in WSNs [3]. The protocol presented here called as Multi-Path and Multi-SPEED routing protocol (MMSPEED), achieves better performance at the expense of higher energy consumption due to more complex computation and longer frame with overhead bits. The MMSPEED uses multipath forwarding by transmitting duplicate copies of the packets and also uses a larger number of hops. This leads to shortening the lifetime of the WSN.

An algorithm for finding multiple disjoint paths to provide communication between two nodes in WSNs is proposed by Li et. al in [4]. This algorithm is a modification of directed diffusion. It uses path-cost metric instead of pure delay in selecting multiple links at the sink for obtaining disjoint paths from the source. While the modifications made in the algorithm take full advantage of the throughput and minimize delay over lossy links in multi-hop WMSNs, they lead to fast depletion of energy in sensor nodes.

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A two-phase geographic greedy forwarding (TPGF) routing algorithm is proposed in [5]. TPGF, working in two phases, determines multiple disjoint paths form the source node to the destination node. However, as data is not transmitted simultaneously through multiple paths, it is less suitable for multimedia data based applications.

Energy efficiency in WMSNs can be achieved by directed diffusion [6] which is based on a data-centric multipath routing protocol. Directed diffusion focuses on energy efficiency at each node and has a drawback of lower security.

ADAPTIVE MULTIPATH PROTOCOL

As mentioned earlier, the multipath data transfer protocol reported in [1] achieves longer lifetime of a wireless multimedia sensor network by choosing to transmit data over multiple paths. While this prolongs the network lifetime, the cost incurred for this is the higher rate of packet loss. If the wireless environment is highly noisy and the probability of communication errors is high, then the additional power required for retransmission may offset the improvement in network lifetime. Considering this, we have proposed an adaptive approach that tries to achieve a balance between packet loss and lifetime improvement. The details of the proposed protocol are described below.

As in [1], there are two steps involved in the algorithm—Route set up phase and Data transmission phase. In the route set up phase, routes are set up and local tables in the sensor nodes are updated. This is achieved by transmitting control messages through relay nodes. Route discovery includes sending messages for multipath discovery and next hop discovery. Details of the route set up phase are same as described in [1]. At the end of this phase multiple paths are found as indicated in Fig. 1.

The proposed new protocol differs from the one described in [1] during the Data transmission phase. It adaptively chooses to transmit data over 1 or more routes depending upon the network condition. Initially, the source node chooses the maximum applicable number of routes that are possible to transmit data to the destination node. As the data packets are being transmitted it monitors the packet drop rate based on the acknowledgment messages received by it. If the packet drop rate is very low then data transmission continues over the chosen routes. However, if the rate of packet loss is much higher, then the source node reduces the number of paths over which data is transmitted until finally a single route is chosen. A flowchart for this protocol is shown in Fig. 2.

SIMULATION

The multipath data transfer algorithm was simulated by using the Qualnet Network Simulator with the parameters as given in Table 1. The simulation was augmented with C++ based simulation for assessing lifetime improvement.

The result of simulation showing energy consumption for cases with 2-5 paths is shown in Fig. 3. As seen here, the total energy consumed by the network decreases with the increase in number of paths used for data transfer. This is to be expected as the use of multiple paths distributes the total data

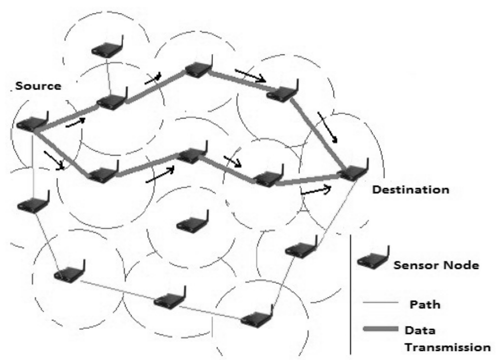

Fig 1: Multiple paths in a WMSN

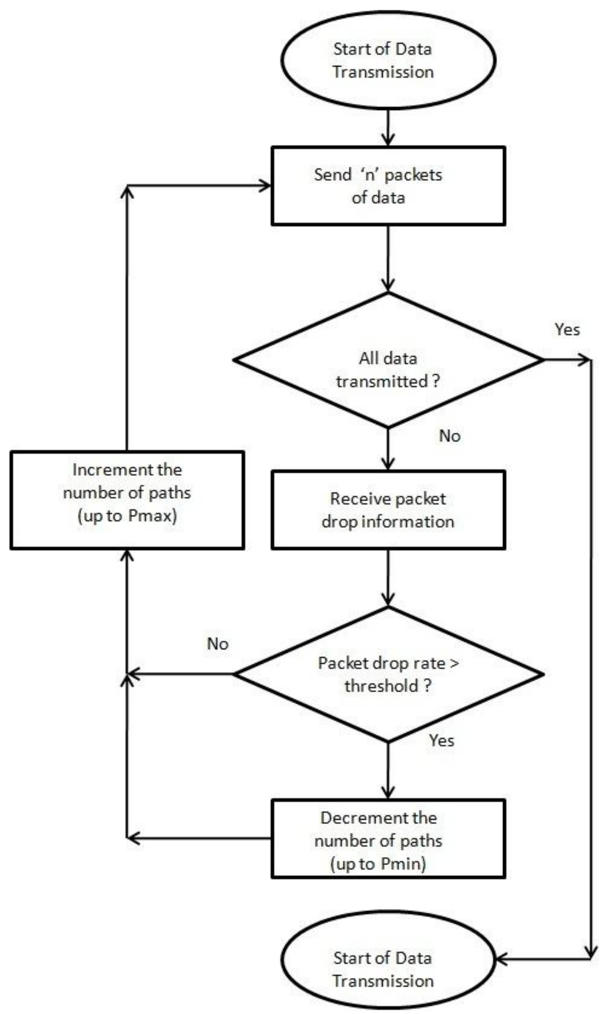

Fig 2: Flowchart for adaptive multipath protocol

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Table 1: Qualnet simulation parameters

Simulation Area (m)	5000 X 5000
Simulation Time (s)	800
Number of Nodes	13
Routing Protocol	MPDT
Channel Frequency	2400 to 2483 MHz

transmission load among the different nodes. In this Figure, node 5 is the sink node and as such it does not transmit any data during the simulation. The decrease in energy consumed directly translates to a corresponding extension of lifetime of the network.

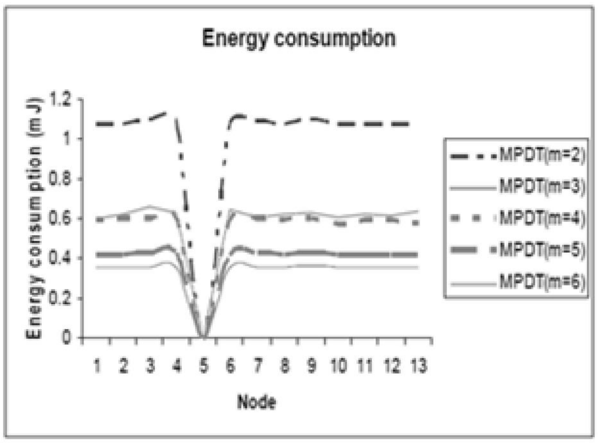

Fig. 3: Energy consumption for multiple data transmission paths

Fig. 4 shows the simulation results for lifetime improvement for the different cases. As seen in the Fig., with the increase in the number of paths, the lifetime of the network also increases. However, as mentioned earlier, with the increase of number of paths for transmission, the probability of packets being dropped also increases. In the multipath case, the channels in all the chosen routes must be error free in order that data is transmitted without errors, and the total number of packets dropped is the sum of packets dropped in each chosen route. Fig. 5 shows the number of packets dropped with respect to the number of paths chosen. As can be seen from the Fig., with the increase in number of paths, packets dropped also increases.

Simulations were carried out for the adaptive multipath data transfer algorithm by combining 2 and 3 path cases. Suppose P2 is the percentage of time the transmission occurs with two paths, and P3 is the percentage of time three path transmission occurs. Then, with different values of P2 from 10% to 90%, packets dropped and network lifetime was found. Figs. 6 and 7 show the results. With the increase in P2, the number of packets dropped reduces but at the same time the lifetime of the network also drops as seen in Fig. 7. Therefore, by adapting the 2 vs 3 path transmission we should be able to achieve a longer lifetime without adversely increasing the packet drop rate. Fig. 8 shows the two parameters plotted with reference to P3. From this plot, it can be seen that around 35 to 50% P3 is desirable for the adaptive selection of paths between 2 and 3.

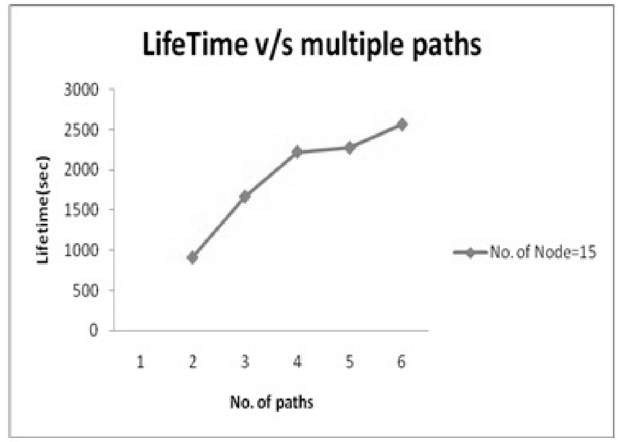

Fig 4: Network lifetime for multiple data transmission paths

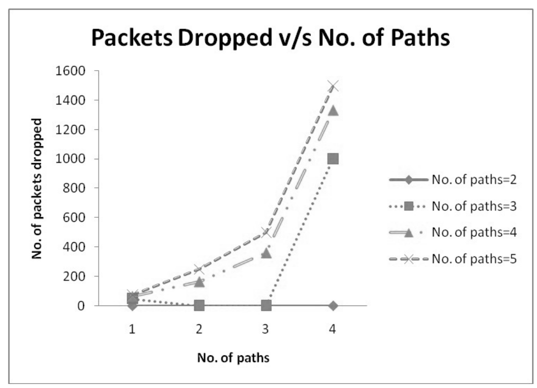

Fig 5: Packets dropped for multiple data transmission paths

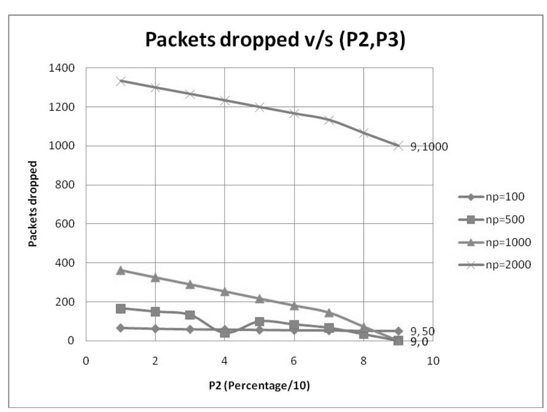

Fig 6: Packets dropped for adaptive MPDT

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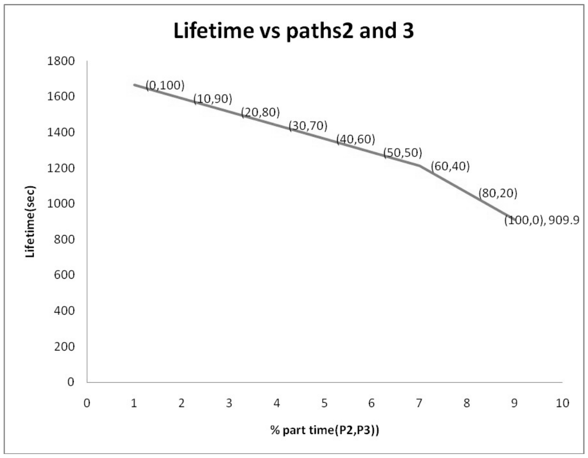

Fig 7: Network lifetime for adaptive MPDT

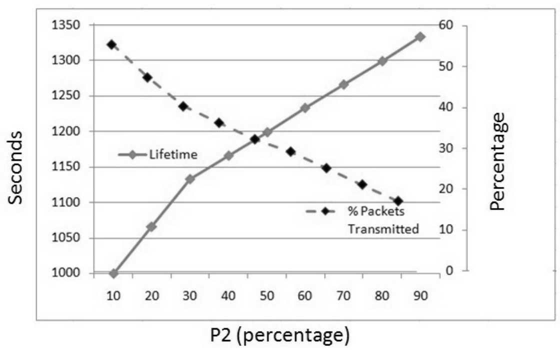

Fig 8: Variation of lifetime and error-free packets for multipath data transmission

CONCLUSION

In this paper, an improvement over the MPDT algorithm of [1] has been presented. While the idea of adaptively choosing different number of parallel paths is new, much more robust study is required for practical application in WMSNs. Simulation results presented are a pointer to the benefits of using the adaptive path choice protocol. A still deeper level of simulation can be done to bring out any operational issues. We hope to pursue further study aimed at working out finer details of the algorithm and to validate it with more robust results.

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