Cross Layer MMRE AOMDV Model for Multimedia Transmission in Wireless Sensor Networks

Santhosha Rao
Dept. of I&CT
Manipal Institute of Technology
Manipal University, Manipal

Kumara Shama
Dept. of E&C Engg.
Manipal Institute of Technology
Manipal University, Manipal

ABSTRACT
With the advent of Wireless Technology, various applications in traditional wired networks have been adopted in Wireless Networks such as Ad Hoc Networks, Wireless Sensor Networks etc. Owing to limited energy in these devices power saving is very critical to prolong the lifetime of these devices. If the objective is to transmit multimedia, it is required to balance the power control and lifetime with the end to end Quality Constraints. Our work finds a mechanism to minimize the energy consumption while satisfying the QoS for Multimedia. In this work, we use cross-layer optimization mechanism based on power control for Maximal Minimal Residual Energy- Ad Hoc On Demand Multipath Distance Vector (MMRE-AOMDV) routing protocol and the optimization mechanism is subject to certain QoS requirement in terms of total end-to end Quality Level. The proposed Sink Based MMRE-AOMDV routing algorithm uses the information such as image size, node gain, noise information available in the route request packets to calculate the optimal power vectors and the number of packets that can be sent by the source for each disjoint path in the route reply packets. The source is freed from the complex algorithmic executions and hence the energy needed for this purpose is conserved. It is assumed that energy is not a constraint for the sink and it has abundant computational power.

General Terms
Cross Layer Routing Algorithm, Wireless Sensor Networks

Keywords
MMRE AOMDV, multimedia, power control

1. INTRODUCTION
The layered open systems interconnection (ISO/OSI) architecture for networking on which the TCP/IP protocol architecture is loosely based, is a successful example of the importance of a good architectural design. These architectures divide the overall networking task into layers and define a set of services to be provided by the individual layers. The layer services are realized by designing protocols for the different layers. The architecture forbids direct communication between nonadjacent layers, and communication between adjacent layers is limited to procedure calls and responses. Protocols must be designed such that each layer protocol only makes use of the services offered by the adjacent lower layer and is not concerned about the details of how the service is being provided.

Wireless networks initially inherited the traditional layered architecture from wired networks. Nevertheless, as third and fourth generation wireless communications and networking begin to proliferate in the area of communication networks, the suitability of the layered architecture is coming under close scrutiny from the research community. It is repeatedly argued that although layered architectures have served well for wired networks, they might not be suitable for wireless networks [1]. One of the key challenges for next-generation broadband wireless networks is to devise end-to-end protocol solutions across wired and wireless networks by leveraging IP technologies while trying to accommodate large densities of highly mobile users demanding services and applications with a wide range of Quality of Service (QoS) requirements. Hence, in order to meet the challenging demands on future wireless networks, it may be required to adopt new approaches in which protocols can be designed by violating the reference layered architecture allowing direct communication between protocols in nonadjacent layers (i.e. creating new interfaces between nonadjacent layers), sharing variables among layers, redefining the layer boundaries, designing protocols at a layer based on the details of another layer, jointly tuning of parameters across layers and so on. Such violations of a layered architecture have been termed as cross-layer design with respect to the reference architecture.

2. LITERATURE REVIEW
At the physical layer, the power control and the modulation are the main adjustment parameters for an energy efficiency communication. Authors in [2] propose an adaptive modulation scheme for Wireless Sensor Networks (WSN) with an Additive White Gaussian Noise (AWGN) channel. Link adaptation can achieve a good performance in term of energy saving in wireless networks.. The results given in [3] have shown that the link adaptation can improve the performance of WSNs. Many energy efficient MAC protocols have been proposed in literature. One of the important mechanisms for achieving low energy operation in energy-constrained Wireless Networks is duty cycling [4]. In these mechanisms each wireless node periodically transits between an active state and a sleep state. Key parameters that characterize the duty cycle include sleep time, wake time, and the energy consumed during the active state and the sleep state. The period of a duty cycle is equivalent to its sleep time plus the active time. Routing problems are usually considered to be very crucial in energy constrained wireless network design. A good routing protocol should be able to select the routes that consume minimal global energy. Hence, a software solution which combines cross-layer and energy aware system design to increase energy efficiency is a promising solution. A large number of routing protocols has been developed for WSNs and detailed in [5]. In [6] the authors proposed a new routing protocol called Maximum Minimum Residual Energy-Ad Hoc On demand Multipath Distance Vector (MMRE-AOMDV) in order to balance the traffic load among different nodes according to their nodal residual battery and

prolong the individual node's lifetime and hence the entire system lifetime. The key idea of the protocol is to find the minimal nodal residual energy of each route in the process of selecting path and sort multi-route by descending nodal residual energy. It can balance individual node's battery power utilization and hence prolong the entire network's lifetime. Simulation results show that the proposed MMRE-AOMDV routing protocol performed better than AOMDV. The authors in [7] have studied network life time maximization of Wireless Sensor Networks (WSN) through joint routing and sleep scheduling. In [8] authors explored an optimal routing to select the next hop node by considering the different cost functions such as distance, remaining battery power and link usage. There are also works reported to optimize the energy for Multimedia delivery in wireless networks. The authors in [9] propose a new cross-layer approach to optimize selectively encrypted image transmission quality in WSNs with strict energy constraint. The authors in [10] proposed a Theoretical Framework for Quality-Aware Cross-Layer Optimized Wireless Multimedia Communications. The authors in [11] developed an image transmission model that allows the application layer to specify an image quality constraint, and optimizes transmit power and packet length, to minimize the energy dissipation in image transmission over a given distance. A Power Aware medium Access Control (PAMAC) protocol is proposed in [12] which enables the network layer to select a route with minimum total power requirement among the possible routes between a source and a destination provided all nodes in the routes have battery capacity above a threshold. Authors in [13] proposed a cross-layer-based routing protocol that can utilize MAC-layer QoS based scheduling for more efficient routing mechanism in WMSNs. The proposed optimization is based on clustered multipath routing protocol and adaptive QoS-aware scheduling for the different traffic classes in WMSNs. A cross-layer design to improve the end-to-end performance of MANET is presented in [14] that allows the network layer to adjust its routing protocol dynamically based on SNR and Received Power along the end-to-end routing path for each transmission link.

3. OBJECTIVE AND SCOPE

Objective of our work is to implement the proposed cross layer model between Physical and Network layer in the energy constrained wireless networks to minimize the total transmission energy consumption while meeting the desired QoS for the image delivery specified in terms of Packet Error Rate. *Scope* is to maximize the lifetime of the battery operated wireless nodes.

4. BACKGROUND THEORY

For the proposed cross-layer model design, we assume that the area in which the network is deployed is modeled as a square, two dimensional space of a given size. In this region, a given number of nodes are distributed randomly. The multimedia packet is sent over a multi hop route, and must be delivered to its destination, the sink with a minimum end-to-end Quality Level. Each hop is modeled by a path-loss AWGN channel, so that for a given hop length d_i there is a one-to-one relationship with the associated channel gain, denoted as g_i.

When transmitting over the i^{th}link with transmission power $P_{Tx,i}$, the received power $P_{Rx,i}$ is given by

$$P_{Rx,i} = g_i . P_{Tx,i} \qquad (1)$$

Where g_i is the link gain and the corresponding SNR is,

$$\gamma_i = \frac{g_i . P_{Tx,i}}{2B\sigma^2 N_f} \qquad (2)$$

Where g_i is the link gain, σ^2 is the Power spectral density of AWGN channel, B is the system bandwidth and N_f is the receiver noise figure. The numerator gives the received power at the $(i+1)^{th}$ hop and the denominator gives the noise power measured at the receiver. This expression is written assuming that interference from the other nodes is totally eliminated. This is possible by choosing suitable orthogonal MAC protocols. The link gain $g_i$can be expressed as

$$g_i = \frac{1}{G.M.d^k} (3)$$

Where G is gain factor for d=1m, M is the link margin, d is the distance in meters and k is the path loss exponent. For the purpose of simulation we have chosen the following parameters:

B = 10kHz, σ^2= -174 dBm/Hz, N_f =10 dB, G= 30 dB, M= 40 dB and k=2.

At the physical layer we assume Differential Phase Shift Keying (DPSK) as the modulation scheme. If a transmission over single hop wireless link is to satisfy minimum Bit Error Rate (BER) the received SNR must be larger than the given threshold γ. Probability of BER for DPSK is related to a function of received SNR as

$$P_b = \frac{1}{2} e^{-\gamma_i} \qquad (4)$$

The end to end packet error rate P_{pe} can be related to end to end bit error rate P_{be} according to the following equation;

$$P_{pe} = 1 - (1 - P_{be})^n \qquad (5)$$

Where n is the length of the packet.

The Quality Factor Q_L which also represents fraction of error free packets received at the sink can be related to P_{be} as

$$P_{be} = q_L = 1 - \sqrt[n]{Q_L} \qquad (6)$$

Let us consider N nodes in the route from source to sink (including source but excluding sink). Let [P_0, P_1, P2,……..P_{N-1}] be the set of transmit powers for the individual wireless nodes. Let [n_1,n_2,n_3, ….. n_N] be the noise powers measured at the receivers in each of the wireless link on the route. Now the end to end optimization problem with the QoS constraint can be formulated as:

$$\min_{P_t} \left(\sum_{i=0}^{N-1} P_i \right)$$

Subject to

$$\prod_{i=1}^{N} (1 - P_{be,i}) = \prod_{i=1}^{N} (1 - \frac{1}{2} e^{-\frac{g_i . P_{i-1}}{n_i}}) \geq q_L (7)$$

5. PROPOSED CROSS LAYER ALGORITHM

The proposed algorithm is run in the sink node which is assumed to have large computational power and no energy constraint. The algorithm is shown below.

```
If (source_node)

{

Broadcast the request packet with m, Q_L, id, E_residual ;

}

Else if (intermediate_node)

{
        g_j = compute_link_gain(l_ij);

        n_j = Noise_Power();

        Attach(j, g_j ,n_j, E^j_residual );
}
Else

{

Find_Node_Disjoint_paths();

For (Each available disjoint path between source and sink)

  {
P_optimal=Find_optimal_power(g_j ,n_j)

        {

          For (i=1 to N)

            {

      If (E^{i-1}_optimal > E^{i-1}_residual- E_Th OR P^{i-1}_optimal > P^{i-1}_max)Go_to_next_route;

            }

Mark_this_route();
Total_Transmission_Energy_route();

}

packet_count=Max_Min_Residual_Energy(E^j_residual,P_optimal);
Assign_to_nodes(P^i_optimal,E_Th,packet_count);
Send_Route_Reply_Packets();
   }
```

A source node will broadcast a Route Request Packet (RREQ) packet to its neighbor nodes when it requires establishing one session to as in k node. Whenever an intermediate node, receives the RREQpacket, the node appends its remaining battery energy, link gain (g_j), node id and average noise power (n_j) and number of packets in the image (m) to this RREQpacket. On receiving the RREQpackets, on the multiple paths the sink node finds all the node disjoint paths which satisfy the quality constraints. For nodes belonging to each path which meets the quality constraint the sink also finds the optimal powers so as to minimize the total energy of the path. Intuitively we can conclude that the path with minimal total energy consumption is the winner. This may be true if we assume that initial battery energy of the nodes is the same. If we assume that initial energies of all the nodes are different, it is required to improve the lifetimes of the nodes with least residual energy. Usually these will be the nodes very close to sink, since these nodes are used by most of the traffic in the network. To improve the lifetime of the network we have to improve the lifetime of the nodes with minimal residual energy.

The sink sorts all the paths in the descending order of minimal residual energies and starts selecting the paths with the maximum minimal residual energies. Each time a maximum minimal energy path is found, the packet count for that path is incremented by 1 and number of packets in the image (*m*) is decremented by 1.The process is repeated until *m* becomes zero and the sink has packet count for each path to be transmitted to source in the RREP packets.

6. NETWORK MODEL

As depicted in Figure.1, 25 sensors were randomly distributed across 150 m x 150 m square area. The transmission range is taken as 40 m and the maximum transmission powers of the nodes are taken as 150 mW. Each sensor node can communicate with the nodes in its transmission range. This is shown using edges in the above diagram. Node 1 is taken as source and Node 6 is taken as sink. There are multiple paths between the source and sink and the Route Request packets flooded from the source reach the sink after traversing multiple paths. The path information carried by these packets can be used to find multiple disjoint paths between source and sink. All the possible paths between source and destination nodes are found using SAGE software (System for Algebra and Geometry Experimentation) version 5.6. In this work, we select disjoint paths with least delay. The first Route Request packet is stored by the sink by default. After receiving the subsequent RREP the sink checks whether the path available in the packet is disjoint with the path information available in the already stored packets are not. If so, the packets are stored otherwise rejected. Using this procedure we got following three node disjoint paths:

Path 1 : [1 2 3 4 5 6]

Path 2: [1 7 9 11 13 15 6]

Path 3: [1 8 10 23 12 14 16 6]

7. RESULTS AND DISCUSSION

The optimal powers for various nodes on each path are computed using optimization tool box in Matlab. Optimal powers (in mW) for Q_L=0.7, 0.8 and 0.9 are shown in the Table-1, Table-2 and Table-3. It can be easily verified that Optimal powers increase with the increase in Quality Factor.

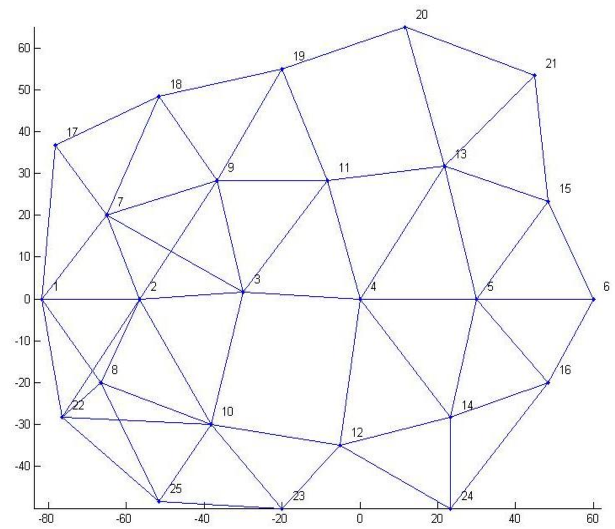

Figure 1: Network Model

Table-1: Optimal Powers of Path-1 nodes for various Quality Factors

Optimal powers for nodes in mW	**Node 2**	**Node 3**	**Node 4**	**Node 5**	**Node 6**
QL=0.7	45.53	51.19	61.11	66.72	64.83
QL=0.8	47.87	53.85	64.36	70.31	68.30
QL=0.9	51.60	58.11	69.56	76.05	73.86

Table-2: Optimal Powers of Path-2 nodes for various Quality Factors

Optimal powers for nodes in mW	**Node 7**	**Node 9**	**Node 11**	**Node 13**	**Node 15**	**Node 6**
QL=0.7	49.58	62.08	57.66	64.72	56.22	49.93
QL=0.8	52.11	65.33	60.66	68.13	59.13	52.47
QL=0.9	56.15	70.53	65.44	73.58	63.78	56.54

Table-3: Optimal Powers of Path-3 nodes for various Quality Factors

Optimal powers for nodes in mW	**Node 8**	**Node 10**	**Node 23**	**Node 12**	**Node 14**	**Node 16**	**Node 6**
QL= 0.7	46.3	64.0	53.4	34.4	60.7	51.0	40.5
QL= 0.8	48.6	67.4	56.2	36.1	63.8	53.6	42.5
QL= 0.9	52.3	72.8	60.6	38.8	68.9	57.8	45.7

After solving the power optimization algorithm, the sink has to distribute these power vectors to individual paths in the Route Reply Packets. Prior to this, the sink has to find the total number of packets that can be sent on each disjoint path according to sink based Maximal Minimal Residual Energy (MMRE) algorithm. The sink sends back Route Reply packets to the source with information such as Optimal power vector, Number of packets to be sent on the path, Residual battery energy of the nodes. The nodes use this updated residual battery energy information in the new route requests.

We assume that the size of the image is 256*256 pixels, source coding rate is 1.25 bits per pixel, and Data Rate is 250 kbps. With the packet size as 1024 bits and the header size as 224 bits, total number of packets N_p required for the image transmission is:

N_p= ceil(256*256* 1.25 /(1024-224)) =103.

We also assume that the residual battery energy exponentially decreases for the nodes on each path in such a way that the nodes closer to the sink have energy lesser than the nodes closer to the source. The residual initial battery energy for the nodes in mJ are assumed as mentioned below:

Initial Residual energy of Path-1 nodes (in mJ): [1720 1680 1620 1560 1420]

Initial Residual energy of Path-2 nodes (in mJ): [1720 1620 1560 1480 1400 1340]

Initial Residual energy of Path-3 nodes (in mJ) [2000 1800 1720 1620 1560 1480 1400]

For each path sink finds minimal residual energy. The sink finds the path index with maximum of these minimal energies. The packet counter for that path will be incremented. After that sink subtracts the optimal energy vector of the path from current residual battery energy and the residual battery energy of the nodes on this path is updated accordingly. The process is repeated until total number of packets on three paths reaches 103.

The Route Reply Packets carry the count information to the individual paths along with the optimal power vectors, updated residual battery energy.

For Q_L= 0.7, energy required for the transmission of single packet(in mJ) on path1, path2 and path3 is 29.6325, 34.8355 and 35.9004 respectively and the total energy consumed by the nodes on path1, path2 and path3 in mJ is 948.2404, 870.8864 and 1651.4 respectively. The packet count for the paths will be 32,25,46 for path1, path2 and path3 respectively.

The updated residual energy of nodes (in mJ) on various paths will be

Path-1 Residual energy: [1570.8 1512.3 1419.8 1341.4 1207.6]

Path-2 Residual energy: [1593.1 1461.1 1412.4 1314.3 1256.1 1212.2]

Path-3 Residual energy: [1781.9 1498.2 1468.1 1457.6 1274.1 1239.6 1209.1]

For Q_L= 0.8, energy required for the transmission of single packet(in mJ) on path1, path2 and path3 is 31.2003, 36.6418 and 37.7324 respectively and the total energy consumed by the nodes on path1, path2 and path3 in mJ is 967.2079, 952.6866 and 1735.7 respectively. The packet count for the paths will be 31,26,46 for path1, path2 and path3 respectively.

The updated residual energy for nodes(in mJ) on various paths will be

Path-1 Residual energy: [1563.1 1503.5 1409.1 1329.6 1196.2]

Path-2 Residual energy: [1586.6 1452.8 1404.7 1305.6 1248.6 1205.7]

Path-3 Residual energy: [1770.9 1482.4 1455.2 1449.7 1259.2 1227.3 1199.7]

For Q_L= 0.9, energy required for the transmission of single packet(in mJ) on path1, path2 and path3 is 33.7080, 39.5284 and 40.6641 respectively and the total energy consumed by the nodes on path1, path2 and path3 in mJ is 1044.9, 1067.3 and 1829.9 respectively. The packet count for the paths will be 31,27,45 for path1, path2 and path3 respectively.

The updated residual energy for nodes on various paths (in mJ) will be

Path-1 Residual energy: [1550.9 1489.6 1392.1 1310.8 1178.0]

Path-2 Residual energy: [1576.3 1439.4 1392.5 1291.6 1236.7 1195.3]

Path-3 Residual energy:[1753.3 1457.0 1434.5 1437.0 1235.4 1207.7 1184.5]

The total energy consumed by the nodes on Path-1, Path-2 and Path-3 with maximum powers in (mJ) is 2841.6 , 2857.0 and 3763.2 respectively.

8. CONCLUSION

The proposed sink based cross layer MMRE-AOMDV algorithm finds the maximum number of packets that can be sent on each path, freeing the source from complex computation which requires abundant energy. It not only improves the lifespan of the network by sending the packets on the maximum minimal residual energy paths but also minimizes the energy consumption of the nodes by optimizing the transmission power for given quality constraint.

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