A ROBUST INTRA-CLUSTER COMMUNICATION FOR WIRELESS MULTIMEDIA SENSOR NETWORKS USING LINK QUALITY ANALYSIS

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Abstract — In recent days the design of Routing mechanism for Wireless Multimedia Sensor Networks (WMSNs) is a challenging task because of rigorous quality of service requirements of multimedia transmission such as packet delay, signal to noise ratio, packet reception rate and jitter etc., Traditional link quality metrics are not suitable for forwarding these high volume of multimedia data and are scarce to meet the expected network life time. Most of the routing techniques focused on assessing the quality of the link to choose better transmission path in order to increase the throughput of network data by using either hardware or software based link metrics for distributed networks. None of them addresses the frequent path failure within the cluster due to dynamic change in quality of the link which will considerably reduce available network energy as well as affects the reliability of the received data packets. In this paper we introduced link quality based multi hop routing protocol called, A Robust Intra-Cluster Communication (RICC) algorithm by taking into account the suitable metrics for estimating the best reliable path for sensor nodes in the clustered architecture. The proposed technique takes account of Link Quality Indicator (LQI), Remaining Energy of a node (RE) and Minimum Hop Count (MHC) as a routing metrics in order to ensure the reliable data transfer and best possible energy utilization of the network. Simulations are carried out and their reporting results are analyzed to evaluate the proposed technique for better utilization of energy and reliable link quality prediction in real-time under various scenarios. Comparative analysis of RICC is done against the Modified AODV protocol in order to prove the reliability nature of RICC in terms of Packet Delivery Ratio, Throughput, Broken link ratio and Life time of the network.

Index Terms — Routing Protocol, Link Quality, Reliability, Multi hop Routing, Cluster Head, WMSNs, Network Lifetime.

1. INTRODUCTION

Recent advancement of micro electronics with CMOS camera sensors and high frequency micro phones enabling the new technology named WMSNs. Sensing and Data forwarding are the main act of this network technology which requires high computing capabilities to deal with multimedia data for various real time and non real time applications [1]. As WMSNs are highly resource constrained and intended to transfer multimedia data such as images, voice and videos etc., traditional Wireless Sensor Networks (WSNs) routing mechanisms are not suitable for forwarding these high volume of data [2]. Radio links in WMSNs are often unpredictable and their quality fluctuates over time by the factors such as the environment, link interference and hardware transceivers which lead to link unreliability. During the wireless communication, routing protocols utilize link quality estimation for increasing the performance of various applications of WMSNs. But, due to the dynamic nature of wireless link such as frequent channel variations and complex interference patterns, assessing the quality of the link is still a challenging problem. Links with poor quality is also affecting the reliable nature of the data path and affects the network life time considerably which has been proven by various existing studies [3] [4] [5]. Link quality is the well-known determinant for assessing the communication performance of the multi-hop routing algorithm in sensor networks. This varies in time with respect to different parameters such as transmission power and nodes hop distance etc [6]. Most of the applications in WMSNs use multi-hop and energy-efficient methods to convey the vital information to the sink. In this paper a new multi hop based routing protocol called RICC has been introduced for WMSN applications which is based on three parameters namely RE, LQI and MHC for choosing the best possible shortest path that promising reliable data transfer and energy utilization of the network. Main Contributions of this paper is as follows:

(i) The proposed method addresses the problem of energy efficient routing by considering the remaining energy of the node thus increasing the lifetime of the network.

(ii) A Routing protocol for Intra- Cluster communication based on combined link metrics assures the reliability of the sending packet by increasing the packet drop rate as well as the lifetime of the cluster topology.

(iii) A constant link monitoring with notification of weak link helps to choose the guaranteed path for data transfer.

Some existing work proved that short distance forwarding nodes extended the lifetime of a wireless network by their proper selection of forwarding candidates based on the theory that when the distance between the neighbour increases, it would consume more power. In this paper, we provide a new routing scheme against the above theory that, in a cluster based environment nodes are not so far as flat architecture and the protocol runs inside each cluster considering the minimum hop count path as a best path for forwarding, thus perform the intra cluster communication effectively with minimum overhead.
The following sections of the paper are ordered as follows: In section 2, a survey of various routing techniques based on link quality is given. Section 3 clears the network model of the proposed technique. In section 4, the description of various routing metrics used in our algorithm is presented. Section 5 discusses the proposed routing methodology and in section 6, the performance analysis of the proposed algorithm is explained. Finally in section 7 the conclusion of the paper and future work is revealed.

2. RELATED WORK

In many real time deployments of WMSNs, Link quality estimation is a critical component for wireless communications. Various Link qualities based routing protocols for WMSNs are analysed and presented in the literature but still some challenges are uncovered due to the growing need of application requirement of wireless sensor networks. Though there are many existing link based routing techniques, no one common approach to deal the problem of link unreliability and network stability with minimum overhead. This section re-examine some routing protocols, which are based on the link quality and the energy for the real world WSN nodes. Link Quality analysis is an essential tool for the computation of reliable route selection metrics. Protocols using link quality calculation for route selection are addressed in [6][7]. In [7], MultiHopLQI selects the path using additive LQI values of all the links from source to sink node. When choosing the high quality link, the energy consumption is also increased in parallel. This protocol does not consider the remaining energy of the node when selecting the high quality link which result in poor lifetime of the network. A routing algorithm based on lexical structures and link quality evaluation has been proposed in LABILE [8]. Routes with below the threshold are considered very bad and more prone to packet loss. Over use of the same link lead to the premature death of the nodes in that routes. This protocol does not have the mechanism to choose the alternative paths and also not consider the energy of the nodes during the route selection process. Routing protocols that create a multi hop trees to send the data usually share the common destination node will creates many to one traffic. CTP does not address the applicability of it into different kind of IoT applications [9]. Some routing techniques take on remaining energy as a routing metric tend to maintain the lifetime of the network. In [10], the cost of communication between nodes and the remaining energy of the nodes are considered as the routing metrics. The energy consumption of the entire network is decreased considerably and the lifetime of the network is maintained by the proposed algorithm, but fails to grasp high throughput.

4.1. Hop Count Metric

Hop count metric between source node S and destination node D can be defined as number of intermediate nodes between them including the source node. The lifetime of a wireless network can be extended by proper selection of relay nodes that act as forwarding candidates. This system defines the path with minimum number of hops is better than a path with most hops even though it would consume more power than the short hop neighbor. The reason behind this selection metric is that the distance between source and CH would be considerably less than the other architecture and it reduces the unnecessary overhead of discovering routing path on each short hop neighbor. When transmitting the RREQ the packet header includes the NH as parameter which is incremented for every hop.

Figure 2.Hop Count of the path.

The hop count in a link is considered as less number of nodes from the CH, and the nodes deployed within the cluster. Also the distance among the hops lies within the cluster boundary.

5. PROPOSED METHODOLOGY

In the proposed network scenario, Data packet may reach the destination node via various possible paths, among which the RICC selects the optimum path for reliable routing of data packets based on the combined metric that encompasses hop-count, link quality indicator value and residual energy of each node. Periodic notification of link status i.e. the link to be either serviceable or not can also be declared with this protocol with the use of threshold mechanism which in turn ensures the end-to-end link quality, reliability in terms of packet loss rate and improves the node’s life time of various real time and non real time applications of WMSNs. Our proposed protocol choose the best reliable path based on the weighted average of each possible path in that scenario.

Figure 3. Prop up of RICC.

It is calculating the Avg. LQI, Avg. RE and No of hops in each possible path and compute the weighted average in order to select the best reliable path which is considered as the optimal path from sender to receiver. By considering the above three metric our system decides forwarding path that should have Highest average residual energy, Highest average LQI value and Minimum hop count to reach the CH. Nodes send route request to its one hop neighbours. Neighbours forward it to next hop neighbours. This to be continued till it reaches CH. The responsibility of the CH in cluster based architecture is to aggregate the received data packet and forward them further till it reaches the sink node. Whenever the node finding their next hop parent, the process of routing must be initiated on them. RICC agree with various requirements of the wireless network properties which are depicted in figure 5. The routing introduced in our work is mainly focuses on reliability of the received data and to reduce the overall energy consumption of the network by choosing the optimal path based on our proposed metric called combined link.
quality metric. After the reliable path has been discovered by receiver node (CH), it should send the route reply (RREP) to sender about the chosen reliable path.

Figure 4. Flow Diagram of RICC

Sender should follow the path for data forwarding. This process to be continued often should be decided as per the need of the application. The RICC algorithm is divided into two part such as computation of selection metric and route selection mechanism. Step by step pseudo code is given for clear understanding of the proposed algorithm.

5.1 Pseudo code of the Proposed Algorithm

Step 1.
Source node generates RREQ packet with node id and broadcast to ‘n’ neighboring nodes.

Step 2.
Relay nodes update their routing table with the following data
- Observed LQI of the link
- Calculated RE of its own
- Incrementing the Hop count field

Step 3.
Cluster Head computing the cost of available paths and chosen the best optimal path as follows
- CH node receives RREQ packets from ‘n’ number of paths.
- Calculate weighted AVG of each path.
- Choose node with max weighted average as relay node.
- Generates RREP packet to source node through the chosen path.

Step 4.
Source node started data transmission over the selected path. Monitoring of link condition is initiated for each link in that path.

5.2 Route Selection Mechanism

Link quality analysis should start after ensuring the threshold metric. According to the node capacity minimum energy threshold $E_{th}$ and minimum LQI threshold $LQI_{th}$ should be prefixed and CH has to ensure that each relay node of the optimal path should not fall below the threshold value. During the route discovery, the CH calculates Weighted Average of each path based on the selection metrics. The path with highest Weighted Average ($WA$) should be selected as the best reliable route that is depicted in figure 6. The path with highest $WA$ is chosen as the best path and the path with next lower value will be maintained in the buffer as an alternate path if it also satisfies the threshold measures in LQI and RE.

Our proposed protocol considers THC as a third metric when all possible paths have almost equal AVG-LQI and AVG-RE. If number of possible path for a node (x) is n, then after calculating the entire path having equal AVG-LQI and AVG-RE then third metric THC should be taken in to account. Since the path discovery is to done within a short coverage, will not consider the distance between neighbours and also the energy utilisation for neighbour communication, it is sufficient to have minimum number of intermediate nodes to reach the cluster. The below algorithm verifies the link quality can provide the optimal clusters reduce cost and energy. So RICC will take an account of only a path with minimum number of hops. If this too equal for the paths then random selection of the path should be taken. The situation of all the possible path for node having equal values of all the three metric is happen only for rare case.

Our assumed network will never meet this situation. Periodical update of routing table entry for all the three metric should be done for each time route discovery process finished.

5.2.1 Weighted Average Calculation

Consider the path, with Average Remaining Energy as $AVG-RE$, Average Link Quality Indicator value as $AVG-LQI$ and the Total Hop Count of the path, as THC. The weighted Average ($WA$) of path, is calculated as follows

$$WA_{\text{path}_a} = \text{path}_a[AVG - RE + AVG - LQI] - \text{- - - - - (3)}$$

The Average Remaining Energy ($AVG - RE$) calculation is started after ensuring the source which initiates the route discovery and relay nodes in that path with their energy greater than the threshold energy of the network using the following

$$\text{path}_a[AVG - RE] = \frac{RE[S + \sum_{i=1}^{n} R_i]}{TN_a} - \text{- - - - - (4)}$$

where the source node is $S$ and set of relay nodes of the path, is $R$ where $R = [R_1, R_2, ..., R_n]$ and Number of nodes in path, is $TN_a$. If a path which do not meet the energy threshold is marked as invalid.
Similarly the Average Link Quality Indicator (AVG –LQI) Calculation starts by ensuring the LQI of each link in the path to reach destination. A path with LQI is less than the threshold then it is marked as invalid. The Average Link Quality Indicator of path, is calculated as follows

\[ \text{path}_{\alpha}[\text{AVG} – \text{LQI}] = \frac{\text{LQI}_{\sum_{i=1}^{n}E_i}}{\text{TE}_{\alpha}} \]

where the source node is S and set of edges of the path, is E where \( E = \{E_1, E_2, ...E_n\} \) and Number of edges in path, is TE_{\alpha}

### 5.3 Monitoring the Link Failure

In the existing protocols, such as AODV, periodic hello messages are sent to monitor link failure. When hello packets are not returned within a specific time interval, the nodes remove the entry in the routing table and also send a route error packet to all the nodes that have an entry for this link. A route discovery process is initiated on receiving this error message and results in high routing overhead. The packet transmission is disturbed till a new route is discovered. If an error message could be sent before the link completely fails, it would be possible to find a new route before the occurrence of the failure. In our scheme instead of using hello packets, since the LQI value is being continuously computed by the nodes and the nodes energy will be accounted periodically, whenever the link quality falls below a threshold, the node sends an error notification message and there by maintains the network connectivity.

### 6. PERFORMANCE ANALYSIS

This section outline the performance comparison of our proposed algorithm against the variant of typical AODV called EN-AODV by conducting various tests using NS-2 simulator. The network is planned and employed with maximum of 65 nodes which are deployed in 1700x1700m area sensor field, and generates traffic for every 5 seconds.

#### Table1. Simulation Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network size</td>
<td>1700 x 1700 m²</td>
</tr>
<tr>
<td>Number of sensors nodes</td>
<td>50</td>
</tr>
<tr>
<td>Number of camera nodes</td>
<td>15</td>
</tr>
<tr>
<td>Network topology</td>
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<tr>
<td>IEEE standard</td>
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<tr>
<td>Transmission range</td>
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</tr>
<tr>
<td>Transmission power for multi hop data</td>
<td>-10 dBM</td>
</tr>
<tr>
<td>Transmission power for single hop data</td>
<td>-1 dBM</td>
</tr>
<tr>
<td>Number of packets</td>
<td>1500</td>
</tr>
<tr>
<td>Data packet size</td>
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<tr>
<td>Simulation time</td>
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<td>Hello interval</td>
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<td>Hello Loss Allowed</td>
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<td>Data transfer protocol</td>
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<td>Connection type</td>
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<td>Radio</td>
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<tr>
<td>Initial energy (E)</td>
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<tr>
<td>Number of slots (n)</td>
<td>10</td>
</tr>
<tr>
<td>Speed of Sender</td>
<td>0.09 m/s</td>
</tr>
</tbody>
</table>

#### 6.1 Simulation results

##### 6.1.1 Packet Delivery Ratio (PDR)

It is the ratio between numbers of packets received by the destination to the numbers of packets sent by all the sources in a specific duration.

![Figure 6. PDR comparison with increasing simulation time.](image)

Here the traffic is generated by various sensors in the field of simulation and the recipient node is cluster head. The figure 9 shows the reading of PDR measured in different time intervals. It is increased in conjunction with number of nodes in the proposed algorithm when compared to the EN-AODV protocol.

#### 6.1.2 Network lifetime

One of the key parameter of QoS assessment for any routing technique is the network lifetime which enlightens the existence of the network in real world applications. Proposed protocol sustain the lifetime of the network by maintaining the minimum energy of nodes which are not go below the threshold level.

![Figure 7. Nodes alive (%) comparison against time in seconds.](image)

Figure 10 depicts the fraction of nodes active when time extend in seconds for both the protocols EN-AODV and RICC. With the knowledge of residual energy of the nodes and link quality status of nodes, proposed protocol maintaining good network lifetime. Readings from the graph clearly represent that RICC has the lowest value for the node failure range which mean it preserve the good lifetime of the network when compared to the old one.

#### 6.1.3 Throughput

Throughput is an amount of packet is transmitted across a network from source to destination per unit time and is measured in terms of bytes at the destination. Figure 11 clearly shows that the proposed protocol received more number of packets compared to EN-AODV with respect to time because of the packet delay which is high in EN-AODV due to more network overhead. During the packet transmission RICC considerably reduces the delay of packet with the estimated link metric values and optimal path selection method, hence it increases the throughput.

![Figure 8. Throughput comparison of EN-AODV (vs) RICC](image)

#### 6.1.4 Link drop ratio

Figure 12 displays the average percentage of broken links when the protocol is running. The two routing mechanisms are compared using the degree of connectivity.
metric. Here again, best results are produced by RICC which shows the less average percentage of link broken rate when compared to existing one.

Figure 9.Comparison of Broken Link Ratio of EN-AODV (vs) RICC

6.1.5 Network overhead

Figure 1 confirms the control packet overhead ratio value for two protocols for the simulation times from 00 to 120 seconds.

Figure 10.Overhead packets in EN-AODV against RICC

Packet overhead ratio in EN-AODV is greater than RICC. This is due to receiving more route advertisement packet by each node in the path; this again depletes the energy level of the node.

7. CONCLUSION

In this paper, we proposed a robust routing mechanism for clustered network that take the routing decision based on the weighted average of the Link quality metrics to ensure the reliability of some real time applications in wireless multimedia sensor networks. Due to poor link quality assessment, many routing techniques failed to meet the important QoS metric called reliability. This work has shown that the combined link quality metric leads to an efficient way of maintaining nodes lifetime by its energy consumption model and also used very limited control packets for the network to run. In the proposed approach remaining energy of each node in the path is calculated, LQI value of each link is measured and also the hop count of the path is encountered to indentify unreliable nodes the during the route discovery process. A path which has sufficient energy level, minimum overhead, minimum hop count value and maximum LQI average has been selected as an optimal path for the transmission. The proposed protocol has been evaluated against EN-AODV through simulation experiments and the results are compared using various routing metrics such as packet delivery ratio, Network lifetime, Link drop ratio and packet overhead etc., which shown that RICC outperforms the existing approach and can provide a reliable routing approach in the hierarchical cluster based wireless sensor networks.

REFERENCES
