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Cross-layer multipath routing approach and link quality indicator for QoS provisioning in mobile WMSN

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ABSTRACT

With the recent advancement in mobile adhoc networks (MANET's) and technology, applicability, and integration of wireless multimedia sensor networks (WMSN) in MANET's has led to creation of smart distributed system for high-speed mobile multimedia streaming and real time multimedia traffic transmissions. In this paper, we propose cross-layer multipath routing approach with link quality indicator (CLMRLQI) to compute stable link between two nodes. CLMRLQI discovers stable multipath routes by considering cross-layer routing metrics such as energy and bandwidth to support quality of service (QoS). The simulation scenarios are carried on network simulation tool and QoS parameters such as throughput, PDR, delay, overhead and energy consumption are analysed.

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1. INTRODUCTION

It is well known that mobile adhoc networks (MANET's) have offered solutions to wide range of application fields including surveillance, object tracking, health domain, military, under water sensor networks (UWSN), vehicular adhoc network (VANET's), flying adhoc network (FANET's) and environment monitoring [1]-[4]. Advancement in field of wireless technology and multimedia communication has led to the rapid rise of internet of things (IoT) by interconnecting millions of devices and enabling smart services in ubiquitous computing environments [5]-[8]. It is a real challenging task to provision quality of service (QoS) requirements within aforementioned constraints for multimedia transmissions [8]-[14]. However, fails to determine link quality for high-speed mobile nodes, such that the nodes should be aware of their link expiry to switch alternate path and adapt network changes [15]-[17]. In this paper, we propose cross-layer multipath routing approach with link quality indicator (CLMRLQI) to estimate link quality between two nodes. CLMRLQI discovers stable multipath routes by considering cross-layer routing metrics for reliable data transmissions.

Sudha *et al.* [18] proposed improved cross-layer multipath routing for MANET's using swarm optimization to extend network lifetime and increase routing performance. In this routing scheme, fitness metrics such as Abazeed *et al.* [19] proposed multipath routing scheme through cross-layer approach to overcome issues in single path routing technique that cannot guarantee QoS requirement for WMSN. The optimal routing decision is adapted through cross-layer information between physical, network and application layers. Chandravanshi *et al.* [20] proposed energy aware load balancing multipath and multichannel routing scheme with efficient bandwidth usage for MANET's. During data transmission the available bandwidth is divided into sub-channels such that the channel is efficiently shared among nodes and minimizes channel collision. Zhang *et al.* [21] proposed multipath routing scheme based on prediction of link lifetime and energy consumption for mobile nodes. This routing scheme is a modified version of existing adhoc on-demand multipath distance vector (AOMDV) routing protocol. The routes towards destination are determined based on the energy grading strategy. Salah *et al.* [22] proposed mathematical model for path stability and to estimate link quality for mobile nodes. In this routing scheme author considered link and path stability as two important parameters that plays crucial role in nodes mobility. Ren *et al.* [23] proposed multipath cross-layer routing optimization considering QoS constrains for mobile nodes based on intuitionistic fuzzy set theory. The main objective of this routing scheme is to adapt network changes caused due to mobility. Li and Liu [24] proposed monitoring area coverage algorithm based on the nodes position control is proposed to solve the coverage problem of WSNs. Gripsy and Jayanthiladevi. [25] proposed a novel transverse wave zone-based secure location aided routing technique called TWRect with Dynamic Adaptive Secure Routing that makes forwarding decisions based on the node location information and wave zone selection. Pandey and Singh [26] proposed IAMRS multipath scheme. During route establishment process multiple node-disjoint paths are constructed using a reward factor assessed on the basis of lifetime and signal power metrics. Krishnan *et al.* [27] proposed the self-configurable cluster mechanism with the k-means protocol approach was proposed to designate cluster heads effectively, and the Trust Management algorithm was also presented to detect and prevent vulnerabilities in MANET. Chen *et al.* [28] proposed a new on-demand multipath routing protocol (TA-AOMDV) which can ensure the data transfer on a stable path to some extent. Proposed algorithm will not be suitable for high-speed scenarios, which consider both path stability and node density.

Due to nodes movement, network experiences dynamic topology changes and frequent link failures occures. In multihop transmissions, nodes collaborate with each other and select one or more intermediate relay nodes to forward data traffic from source and destination. Determining active link lifetime is a challenging task, predicting link lifetime and path stability increases overall network performance. To maximize network performance, cross-layer approach emphasis on system optimization, allowing different layer to communicate and synchronize and provisions QoS requirements. This motivates us to propose CLMRLQI to predict the link quality between two moving nodes, such that node is aware of its link failure in advance. This helps nodes to switch between paths to maintain route stability and to be adaptive for dynamic topology and tackle constraints.

2. METHOD

2.1. Network model

Network comprises of mobile wireless multimedia sensor nodes (MMSN), The network graph consisting of nodes and link between nodes is represented as $G = (n, l)$, where n is the number of mobile nodes and l is the link between two nodes. The topology changes between any time instant t to $t + \Psi t$, within time duration T and the $\Psi t$is obtained by computing link quality indicator (LQI). The distance between two nodes n_i and n_j with transmission range R and coordinate values (X_i, Y_i) and (X_j, Y_j) is evaluated from Euclidean distance equation which is calculated as:

$$D_{n_{(i,j)}} = \sqrt{\left(X_i - X_j\right)^2 + \left(Y_i - Y_j\right)^2} \quad (1)$$

distance travelled by node at variable speed S is calculated as:

$$S_V(n) = \frac{D(n)}{T(n)}\ m/s \quad (2)$$

where, $D(n)$ is the distance travelled by node and $T(n)$ is time taken to travel.

2.2. Mobility model and bound of nodes speed

CLMRLQI employs random waypoint mobility (RWP) model to estimate nodes mobility speed, link status and movement direction at time $\theta\, T$. The precise location of the node is provided by GPS. Nodes moving at different speed range given as $[V_{max}, V_{min}]$ and direction of node ζ, between $[0, \pi]$. If present location of node n_i at time instant t, is given as $\left(X_i(t), Y_i(t)\right)$, the updated new location after time increment $\Psi\, T$ is determined as:

$$\begin{cases} X_i(t + \theta\, T) = X_i(t) + \theta\, T * v_i(t) cos\zeta_i(t) \\ Y_i(t + \theta\, T) = Y_i(t) + \theta\, T * v_i(t) sin\zeta_i(t) \end{cases} \quad (3)$$

where node speed is denoted as $v_i(t)$, $\zeta_i(t\ )$ represents nodes direction of $i\ th$ node at time t.

2.3. Link quality indicator (LQI)

LQI denotes the active link life exists between two nodes. The length of link lifetime between two nodes n_i and n_j within transmission range R of each other and nodes are aware of its initial location (X_i, Y_i) and (X_j, Y_j), node velocities v_i and v_j and directions ζ_i and ζ_j $(0 \leq \zeta_i, \zeta_j \leq \pi)$ respectively, will be connected without any link interruption. Link quality between two moving nodes n_i and n_j can be estimated as:

$$LQI_{ij} = \frac{-(ab+cd)+\sqrt{(a^2+b^2)R^2-(ad-bc)^2}}{(a^2+c^2)} \tag{4}$$

where $a = v_i cos\zeta_i - v_j cos\zeta_j$: $b = (X_i - X_j)$: $c = v_i sin\zeta_i - v_j sin\zeta_j$: $d = (Y_i - Y_j)$.
The link status is denoted as:

$$LS_{ij}(t) = 1 - e^{\frac{-LQI_{ij}}{\varphi}} \tag{5}$$

where φ is the constant. Link status considering distance between two nodes is expressed as (6).

$$LS_{ij}(t) = 1 - e^{\frac{LQI_{ij} * D_{n(i,j)}}{\varphi}} \tag{6}$$

2.4. Energy model

In proposed CLMRLQI, the energy efficient nodes are selected by evaluating residual energy. Nodes are assigned with same initial energy and to estimate nodes energy consumption and residual energy at time period θ is given as (7).

$$E_{Res}\,(t_n + \theta) = E_{Int}(t_n) - E_{Cons}(t_n + \theta) \tag{7}$$

Energy consumed to send and receive data packets by node to overcome link fluctuations for unstable links is expressed as:

$$E_{t(x)}\,(t_n + \theta) = D_{sent} \times P_{t(x)}(t_n + \theta) \tag{8}$$

similarly, energy consumed to receive data packets is given as:

$$E_{r(x)}\,(t_n + \theta) = D_{receive} \times P_{r(x)}(t_n + \theta) \tag{9}$$

total energy consumed during transmission, reception and computation is expressed as:

$$E_{Cons}(t_n + \theta) = E_{t(x)}\,(t_n + \theta) + E_{r(x)}\,(t_n + \theta) + E_{Comp}\,(t_n + \theta) \tag{10}$$

residual energy of node is calculated as (11).

$$E_{Res}\,(t_n + \theta) = E_{Int}(t_n) - \left[E_{t(x)}\,(t_n + \theta) + E_{r(x)}\,(t_n + \theta) + E_{Cons}(t_n + \theta)\right] \tag{11}$$

During route discovery, the source node generates control message such as route request (RREQ) packet and broadcast RREQ along with the additional fields such as energy bandwidth and link quality. During route reply, each intermediate node replies RREP packet and computes path stable probability of the discovered path and the RREP packet travels backwards from destination and terminates at source. CLMRLQI updates routing entries in the routing table and re-broadcast the RREQ with additional information and deletes unstable link as shown in Algorithm 1.

Algorithm 1. CLMRLQI
```
Step 1: route discovery Process
        source generates RREQ packet and broadcast to intermediate neighbour node.
               additional field such as energy level, bandwidth and link quality is added in
               RREQ packet
               compute link quality and update LQI between two nodes

Step 2: route reply
        neighbour node after receiving RREQ packet, replies with RREP with path stability
        probability.
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        RREP packets travel backwards and terminate at source.
        if path stability probability is satisfied, then
        primary path along with alternate multipath are constructed.
        end if
Step 3: route maintenance
        while monitoring the established path during route maintenance
        if link interruptions occur then,
        node immediately switches to alternate path by adapting cross-layer information,
        then
        computes LQI_ij , LS_ij(t), E_Res (t_n + θ) then
        route data through alternate paths
        end while
        end if
        end if
```

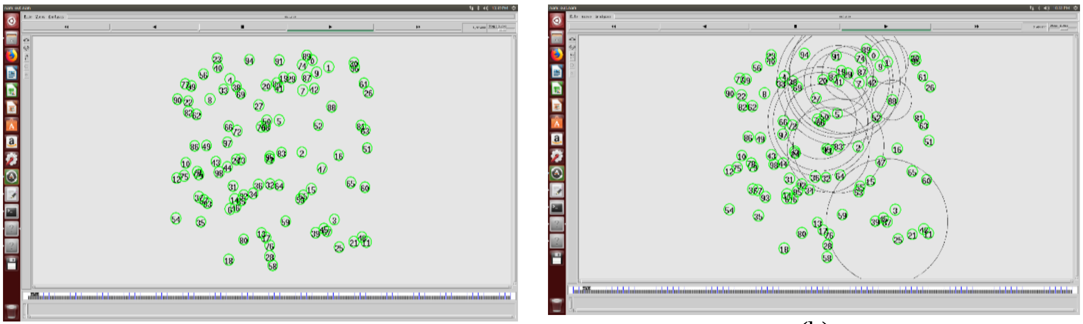
3. RESULTS AND DISCUSSION

3.1. Simulation environment

In Figure 1 represents simulation scenarios, Figure 1(a) represents simulation scenarios 1 and Figure 1(b) represents simulation scenarios 2. Simulation experiment setup is carried out on event driven network simulation NS2 and scenarios for high-speed mobile nodes are conducted. network of 100 Nodes are randomly deployed in a network area of size 800×800 mts. Nodes are mobile in nature and random way point (RWP) mobility model is adopted. Nodes are assigned with the same initial energy level and are homogeneous, constant bit rate (CBR) traffic is utilized. Complete simulation parameters used are shown below Table 1. and Simulation Scenario Proposed CLMRLQI is compared with existing ECTSA and LLECP-AOMDV.

Table 1. Simulation parameters

Parameters	Value
Simulator tool	NS2
Network area	800×800 mts
Node size	100 Nodes
Nodes deployment fashion	Random
Mobility model	Random way point (RWP)
Mobility speed	15,30,45 and 60 m/s
Cross-layer	MAC and Network
Simulation time	100 sec
Energy level assigned	100 Joules
Propagation model	Two ray Ground
Traffic type	CBR



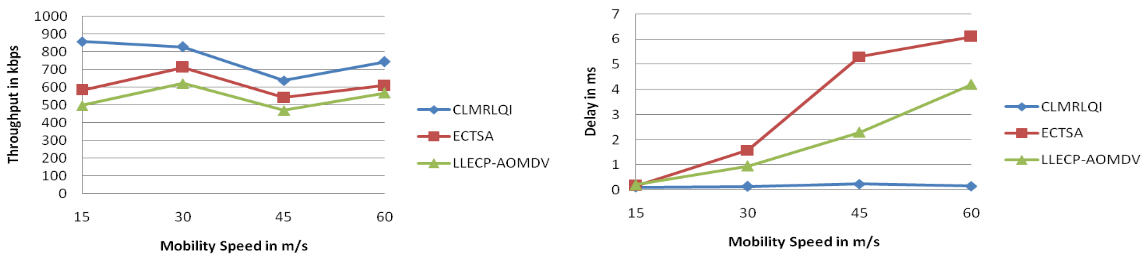
(a) (b)

Figure 1. Simulation scenario; (a) scenario 1 and (b) scenario 2

To explore the scenarios, mobility speed of nodes varied from 20, 30, 40, and 50 m/s. The performance evaluation of the proposed protocol is compared with existing ECTSA and LLECP-AOMDV based on relevant performance metrics such as, the number of packets dropped, delay, throughput, energy consumption, routing overhead. Figure 2 Shows the comparison of throughput for CLMRLQI, ECTSA and LLECP-AOMDV. It is observed from the graph, as the mobility speed is varied the different throughput different protocol have different throughput. When the mobility speed is varied to 15, 30, 45, and 60, when the node is at high speed, the throughput of ECTSA, LLECP-AOMDV and CLMRLQI has throughput of 609 kbps, 567 kbps, and 567 kbps respectively. Nodes move randomly to different positions with different directions and speed. CLMRLQI achieves better throughput as it selects path based on link quality and path stability. Figure 2(a) shows the comparison of average end-to-end delay for CLMRLQI, ECTSA and LLECP-AOMDV. Figure 2(b) shows the comparison of delay vs mobility speed. It is observed from the graph, as the mobility speed is varied, the network experiences delay variations for different protocol. CLMRLQI has delay of 0.16 ms compared to ECTSA delay of 1.66 ms and LLECP-AOMDV delay of 4.23 milli seconds.

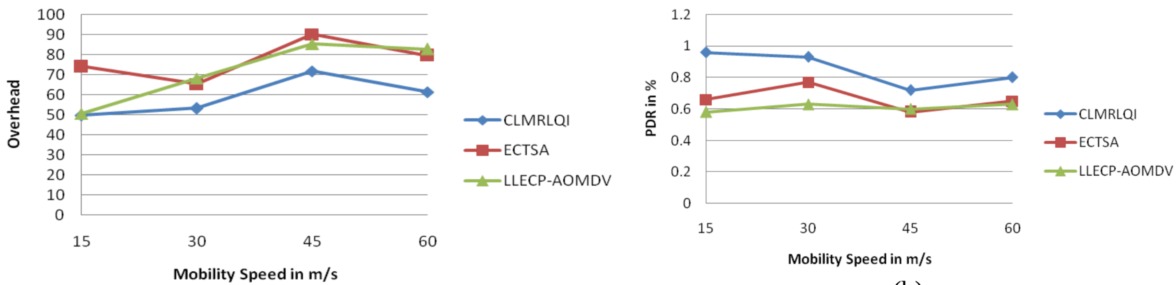
Figure 3 shows the comparison of routing overhead for CLMRLQI, ECTSA and LLECP-AOMDV. It is observed from the graph, as the mobility speed is varied, the network experiences higher routing computation overhead. CLMRLQI has reduce overhead of 61.4 compared to ECTSA of 79.6 and LLECP-AOMDV of 82.8. Figure 3(a) shows the comparison of packet delivery ratio for CLMRLQI, ECTSA and LLECP-AOMDV. Figure 3(b) shows comparison of PDR vs mobility speed. It is observed from the graph, as the mobility speed is varied, the PDR decreases for all the three routing schemes. However, ECTSA and LLECP-AOMDV has PDR of 65% and 63% compared to CLMRLQI of 80%.

Figure 4 shows the number of packets lost. It is observed from the graph, CLMRLQI has packet loss of 43 compared to packet loss of ECTSA and LLECP-AOMDV which has higher packet loss of 74 and 62 respectively. Figure 4(a) shows the comparison of packet delivery ratio for CLMRLQI, ECTSA and LLECP-AOMDV. Figure 4(b) shows the comparison of energy consumption vs mobility speed. It is observed from the graph, as the mobility speed is varied, the energy consumption for all the three routing schemes increases. ECTSA and LLECP-AOMDV has higher energy consumption of 11.6 and 13.2 Joules compared to CLMRLQI of 8.4 Joules.



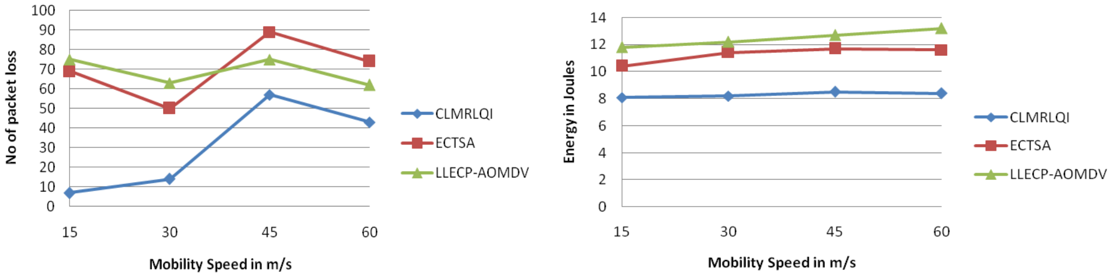
(a) (b)

Figure 2. Comparison of (a) throughput vs mobility speed and (b) delay vs mobility speed



(a) (b)

Figure 3. Comparison of (a) overhead vs mobility speed and (b) PDR vs mobility speed



(a) (b)

Figure 4. Comparison of (a) No. of packet loss vs mobility speed and (b) energy consumption vs mobility speed

4. CONCLUSION

Wireless multimedia sensor networks (WMSNs) have emerged as a powerful and prominent method for delivering multimedia contents such as images, audio and videos. With hardware advancement, sensor nodes are equipped with both mobility and multimedia functionalities to serve as smart devices in mobile multimedia sensor networks (MMSN). In this paper, we propose a CLMRLQI to compute stable link between two nodes. CLMRLQI discovers stable multipath routes by considering cross-layer routing metrics such as energy and bandwidth to support QoS. Simulation results show, proposed CLMRLQI outperforms existing ECTSA and LLECP-AOMDV schemes in terms of throughput, delay, PDR, overhead and energy consumption. In future, congestion aware schemes may be designed to overcome packet drops and to avoid channel collision due to retransmission caused by link failures for high-speed mobile nodes.

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