

A Novel Routing Framework for supporting Distributed Services in LTE systems

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Abstract— Future generation cellular networks are expected to provide distributed services and broadband access to a continuously growing number of mobile users. Long Term Evolution (LTE) technology has emerged as a cost effective solution to Internet broadband access for both stationary and mobile hosts. To efficiently support the large number of customers in the LTE network, the network is expected to support distributed services. Unfortunately, LTE networks do not support network services because of the absence of a dynamic routing algorithm that would locate the destination even if the mobile node moves from one cell to another. A routing algorithm for computing bandwidth guaranteed paths using Distributed Routing algorithm with Controlled Flooding (DRCF) to support distributed services in LTE is proposed in this paper. We have used AODV as the benchmark algorithm to compute the performance of the proposed algorithm. Our conclusions are based on four important performance metrics: 1) Route discovery time, 2) Delay, 3) Total errors sent and 4) Total packets dropped.

Keyword- LTE, DRCF, Route discovery time, Delay, Total errors sent, Total packets dropped

I. INTRODUCTION

The evolution of wireless networks technologies have made internet access more flexible. Internet access is now accessible on the move. Wireless networks enable users to access the internet from any place, unlike the wired network which provides only fixed point of network attachment. In the recent years, WLANs and cellular networks have gained much importance in replacing wired networks for internet access. Nowadays WLANs are successfully deployed in home and office environments for internet access; however they are not suitable for mobile users because of narrow coverage and lack of mobility support. Cellular networks on the other hand provide wider coverage and better mobility support. This makes it more suitable for mobile users. On the contrary, communication cost and narrow bandwidth of the cellular network makes it less attractive for internet access.

(LTE) technology [1, 2] has been proposed to overcome the critical problems of WLANs [3] and cellular networks. It provides greater coverage area and better mobility support while[4,5] encouraging high transmission rate. In addition, it also supports heterogeneous traffic by means of various QoS scheduling. LTE also provides a solution for scenarios that are too remote to receive internet access via cable or DSL. The LTE technology can be used for creating a wide-area wireless backhaul network. With the deployment of backhaul-based LTE many value added services can be provided to the service area [4].

To efficiently support the large number of customers in the LTE network, the network can be enabled with distributed services [5, 6, 7]. In other words, a customer can access the particular service from any of the servers in the network in which the servers are distributed to serve the entire metropolitan area. In this method, the customer does not specify the exact address of the server in the network which runs the particular service; whereas it only indicates the service it wants to access. Moreover, in such a network scenario, more than one server may provide the same service and the customer can establish communication with any of the servers for better reliability. A novel routing framework in the network layer is required in LTE to support distributed services.

Traditional routing algorithms like Dynamic Source Routing (DSR) [8], Temporally-Ordered Routing Algorithm (TORA) [9], Ad hoc On-demand Vector Routing (AODV) [10, 11] are not so effective in supporting distributed service in LTE, as the routing in LTE happens through the base station and the mobile nodes, unlike, other wireless networks where the similar type of nodes will be employed for routing between source and destination. So reconfiguration of base station is necessary to support routing in LTE. In this paper, we propose a Distributed Routing algorithm with Controlled Flooding (DRCF) to support distributed services in LTE. The algorithm is developed to support the LTE architecture [1,2,4] and the performance of the algorithm has been compared with AODV, which is a benchmark routing algorithm.

The rest of the paper is organized as follows. In section II, we discuss the existing approach namely AODV. In section III, we introduce the new routing algorithm and present an overview of the various stages in the algorithm. In section IV, we give the detailed explanation about the network model, base station and subscriber station parameters. In section V, we explain the performance metrics on which the performance of the algorithm is compared. In section VI, we evaluate the performance of DRCF. Finally, we summarize the paper.

II. AODV (AD HOC ON-DEMAND DISTANCE VECTOR)

For the sake of conceptual clarity we first introduce the AODV algorithm and later describe how the algorithm is modified to suite LTE networks. AODV is a distance vector routing algorithm, which discovers route whenever it is needed via a route discovery process. It adopts a routing algorithm based on one entry per destination i.e., it records the address of the node that forwards the route request message. AODV possesses a significant feature that once the algorithm computes and establishes the route between source and destination, it does not require any overhead information with the data packets during routing. Moreover the route discovery process is initiated only when there is a free/available route to the destination. Route maintenance is also carried out to remove stale/unused routes. The algorithm has the ability to provide services to unicast, multicast and broadcast communication. AODV routing algorithm has two phases.

A. Route discovery phase

When a node wants to send some packets to the desired node or destination, it tries to look into the routing table for its next hop. Then the source sends RREQ message to the neighbors or next hop, which is then retransmitted by the intermediate node until the RREQ reaches the destination. To avoid the route request packets from congesting the network, the algorithm uses expanding-ring strategy. In this technique, the node, which tries to send the packets, sets the initial value of the TTL (time-to-live) to search the destination. If the RREQ reaches the next hop, TTL is decremented. If not reached/no reply is received, the value is incremented till it reaches the threshold value.

When an intermediate node receives the RREQ, it stores the address of the adjacent node from which it receives the first packet of the route request message, so that the node will be capable of establishing a reverse path. When route request RREQ message reaches the destination node, a unicast route reply RREP message is sent along the reverse path. As the RREP traverse along the reverse path, forward path entries to the destination are recorded. Hence the route from source to destination is established when route reply message is received at the source.

B Route maintenance phase

The route established between the source and destination is maintained as long as the route is needed by the source to transmit packets. Source can reinitiate route discovery phase to establish new route when it moves during routing of packets. In other case, if the destination/intermediate node breaks from the routing chain, route error RERR message is sent to the nodes in the route till it reaches the source. Upon receiving the route error message, the source stops the data transmission and reinitiates the route discovery process.

III. DRCF ROUTING ALGORITHM

Routing algorithms like AODV, DSR and TORA are designed for wireless networks like MANET. The AODV routing algorithm performs better than the other routing algorithms in wireless environment where nodes can be a fixed or mobile [12]. In LTE networks, the transmission and reception of control signals and packets is done with the help of base station without which operation of the subscriber station is impossible.

In AODV algorithm, the routing to destination is done with the help of intermediate nodes, whereas, in LTE it is done via base station and the subscriber station (mobile nodes). Since the base station is immobile, it is easy to establish a route to the destination from source but maintaining a route is difficult when the subscribers are mobile. Hence, the traditional routing algorithms fail to support distributed services in LTE environment. A dynamic routing algorithm is required to serve the LTE environment especially when the mobile nodes move across cells.

Here we introduce a new routing algorithm to maintain a route along mobile nodes when destination (wireless server or mobile node) moves across the cell. The intermediate nodes are base stations and hence they are stationary. The routing should be appropriate such that it can handle the mobility of source and destination. When the source (subscriber station) sends a route request message, the base station receives and transmits it to all the nearby base stations in order to find the route to destination. This will create an additional overhead in the base stations, which is not in the route to destination. So we set a TTL initial value for the request message to traverse across the base stations. TTL value is incremented till it reaches its threshold value. Once the TTL value reaches the threshold the packet is dropped. This can also be achieved using controlled flooding. The process of RREQ generation is described below:

Initialize TTL

Loop: Broadcast RREQ

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Update TTL & set Reverse path
If RREQ found destination then
    stop Broadcasting RREQ and send RREP
Else
    Buffer address
    If TTL threshold is reached then
        End this process
    Else
        Goto Loop:
    End
End
End

```

Generate RREQ Algorithm

When the RREQ message reaches the destination, route reply RREP message is sent along the reverse path. In other case, if more than one destination replies for the request, there arises a problem in ensuring QoS scheduling service. In this case, the proposed algorithm will automatically check over the various parameters like QoS [13, 14], load and throughput at particular node and take a decision on which node to choose.

The network model is denoted by $G(V, E)$ in which V is a set of base stations in the model and E represents the set of subscribers and servers. This model can be used to represent a LTE network in which individual nodes are the base stations of the model connected through wireless links.

Node degree: Degree of a node x , $d(x)$, represents the number of base stations directly connected with x . Minimum degree of a graph G is then defined by equation (1).

$$d_{min}(G) = \min\{d(x)\} \forall x \in G \quad (1)$$

A similar term is the average node degree defined by equation (2).

$$d_{min}(G) = \frac{1}{n} \sum_{s=1}^n \{d(x)\} \quad (2)$$

For a given node density ρ and transmission range r_0 , to ensure that a randomly chosen node will have exactly n_0 neighbours. Probability P , that a node has exactly n_0 neighbours is given by equation (3).

$$P(d = n_0) = \frac{(\rho \pi r_0^2)^{n_0}}{n_0!} * e^{-\rho \pi r_0^2} \quad (3)$$

The initial RREQ broadcasted by the source is received by d_{avg} nodes, the average degree of a node. Each one of d_{avg} neighbours rebroadcasts the RREQ with probability P_r and hence, the first hop rebroadcasting nodes equal $P_r \times d_{avg}$. The receiving nodes rebroadcast the RREQ with probability P_r , and the process continues. As the SS moves away from the source node, ideally expected forward degree d_f should reduce at every step. To compute total expected routing overhead, the total number of RREQs, C_p , can be accumulated and injected into the network up to h hops from the source node. This cumulative term is given by equation (4).

$$C_p = 1 + \sum_{i=1}^{h-1} d_{avg} (P_r^i * d_f^{i-1}) \quad (4)$$

Receive RREP Packet

Set Forward Path

If Source Node Reached or Found then

Start data transmission

Else

Update Next Hop Information

Unicast RREP via Reverse path

End

Receive RREP Algorithm

After determining and ensuring the proper flow of data along the route, a situation may arise in which the source or destination moves across a cell area. When the source moves away, the route discovery process is reinitialized to find the route. But the movement of destination results in route error, and a route error message RERR will be received at the source.

Node Receives data

Loop1: Initiate Proxy RREQ (P)RREQ

If Proxy RREP is received then

 Add entry in queue

 If RREQ retries exhausted then

 Goto Loop1

 End

 Select proxy node from queue

 Send data from proxy

 If message time out then

 Discard data

 Else

 Store data locally

 End

Else If RREP is received then

 If more than one route reply then

 Check for valid QoS

 Select Destination

 AODV Operation

 Send data

 Else

 AODV Operation

 Send data

 End

End

Proxy Setup Algorithm

In a generic process, the process of identifying the route has to be initiated from the source. But in this paper, we propose a novel methodology wherein we introduce a proxy node (BS) as a source to reinitialize the route discovery process as described in the proxy setup and proxy persistent algorithm. When a subscriber node moves from one cell to another without the termination of connection with the base station, we call it as handover. But in routing, the established route breaks and the route has to be re-established again. In this case, BS which corresponds to the old position of subscriber will act as proxy source node. To establish the route to the new position of subscriber node, the proxy node reinitializes the route discovery process and completes the data transmission. Here again, the acceptable level of the QoS service should be allotted. The algorithm was developed with the help of Stochastic Network Calculus [15].

Node Received Proxy RREQ (P) RREQ

If Destination Reached then

 AODV Operation

Else If Destination Not Reached then

 Check for proxy

 If Node Eligible for Proxy then

 Add (P) RREQ in Database

 Send (P)RREQ

 Broadcast (P)RREQ

 Wait for Data

 If Data received then

 Store data

 Else

 End Process

End

Else If Node not Eligible for Proxy then

Broadcast (P)RREQ

End

End

Proxy Persistent Algorithm

IV. NETWORK MODEL

The network model was configured with 12 Base Stations and 8 Mobile Stations connected to each BS. A simulation area is of 10km x 10km is chosen. The configuration parameters of BS and MS are given in the Table 1 and 2. The base station connected to the IP cloud (internet) has height of 35m and all the other base station has height of 25m. All the subscriber station has height of 1m. Gain of antenna in base station is set as 15dBi and for subscriber station it is -1dBi. All BSs are connected together via a high speed microwave links.

Traffic characteristics specify the match criteria for mapping higher layer traffic to LTE service flows. Match value in the traffic characteristics attribute denotes the type of traffic it supports. For the match value of Best Effort and Excellent effort it supports FTP and HTTP traffic (Table 1).The channel condition requires robust and modulation scheme for downlink and uplink service flow, QPSK scheme is chosen and the coding rate of $\frac{3}{4}$ is used (Table 2).

Table I
Base Station Parameters

Antenna Gain (dB)	15Db
BS Parameters	Default
Traffic Characteristics	
Match Property	IP ToS
Match Condition	Equals
Match Value	Best Effort(0)
Service Class	Bronze
MAC Address	Auto Assigned
Maximum Transmission Power	0.5W
PHY Profile	WirelessOFDMA 20 MHz

Table II
Mobile Station Parameters

MS Parameters	
BS MAC Address	Distance Based
Downlink Service Flows	
Initial Modulation	QPSK
Initial Coding Rate	$\frac{3}{4}$
Average SDU Size	1500 bytes
Service Class	Gold
Activity Idle Timer	60 seconds
ARQ Parameters	Disabled
CRC Overhead	Disabled
PDU Dropping Probability	Disabled

V. PERFORMANCE METRICS

To compare the performance of the DRCF algorithm with benchmark algorithm, AODV, the following performance metrics were used.

A. Route Discovery Time

The time to discover a route to specific destination is the time when a route request is sent out to discover a route to that destination until the time a route reply is received with a route to the destination. The statistic represents the time to discover a route to a specific destination by all the nodes in the network.

B. Delay

Delay represents the end-to-end delay of all the packets received by the LTE MACs of all the LTE nodes in the network and forwarded to the higher layer.

C. Total Route Errors Sent

This statistic represents the total number of route error packets sent by all nodes in the network.

D. Total Packets Dropped

When no route is found to the destination, the node drops the packets queued to the destination. This statistics represents the total number of application packets discarded by all nodes in the network.

We chose the above performance metrics because we believe that they characterize the most important aspects of QoS routing algorithm.

VI. RESULTS

In terms of route discovery time of the algorithms (DRCF and AODV), it can be seen that the proposed algorithm requires more route discovery time as illustrated in Figure 1. This is because the algorithm requires time to setup the proxy node. The proxy node will once again initiate the route discovery process to find the new route to destination. However, proposed algorithm takes only a few extra milliseconds to compute the route than AODV, which is acceptable given the reliability and flexibility it provides for mobile users.

The delay experienced by both the routing algorithms is approximately same as illustrated in Figure 2.

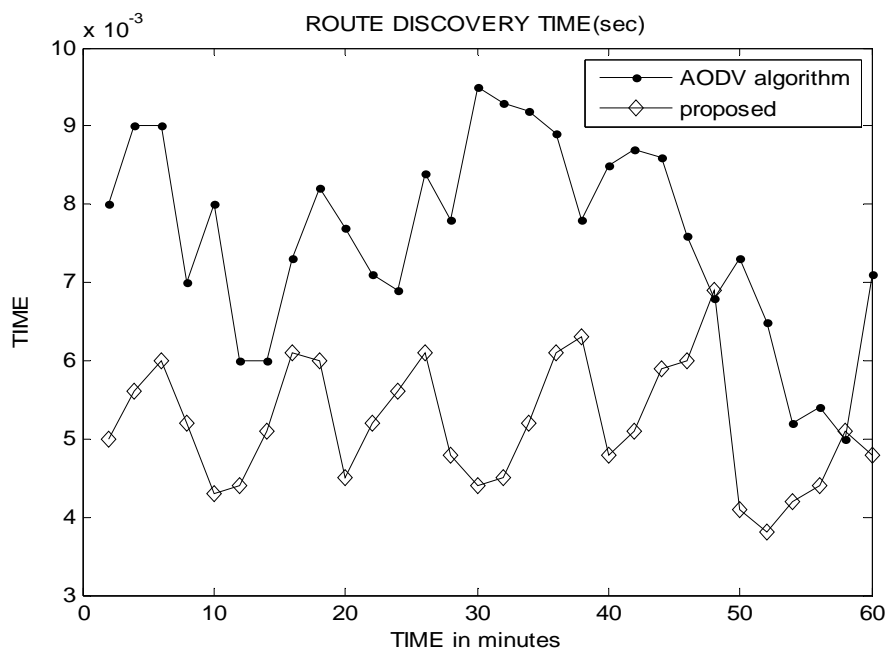


Fig. 1. Route Discovery Time

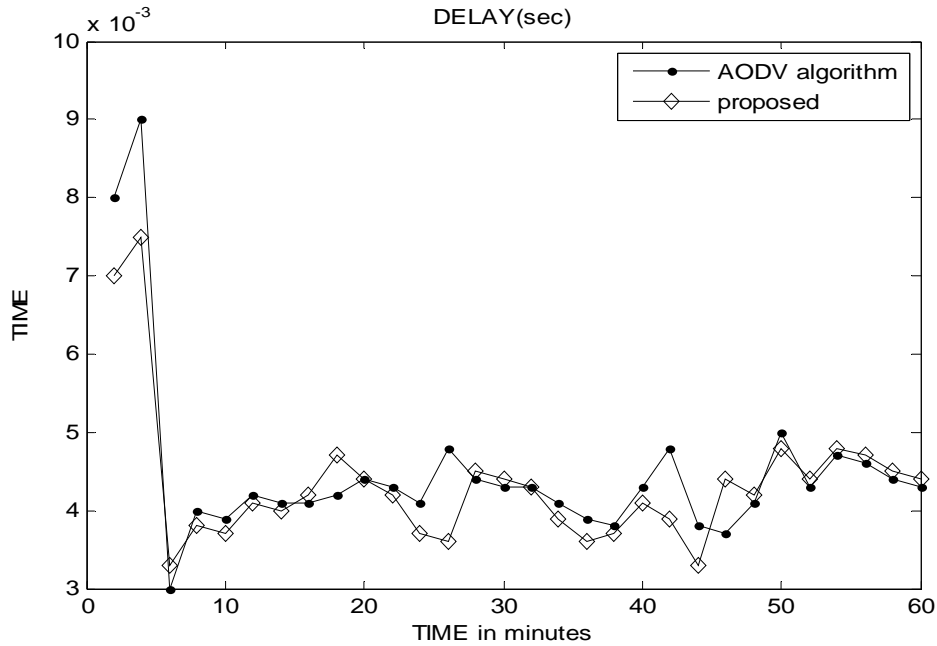


Fig. 2. Delay

The observation from Figure 3 shows that in terms of total errors sent, the proposed algorithm outperforms AODV. The number of route errors sent for the proposed algorithm is 2 whereas it is 3 for AODV. This is because setting up of proxy node will reduce the number of route errors. Considering the size of the network scenario, which is small, this is a significant improvement.

The most interesting improvement of DRCF over AODV is with respect to total packets dropped as illustrated in Figure 4. With respect to total packets dropped, the proposed algorithm is about 60 percent better than AODV.

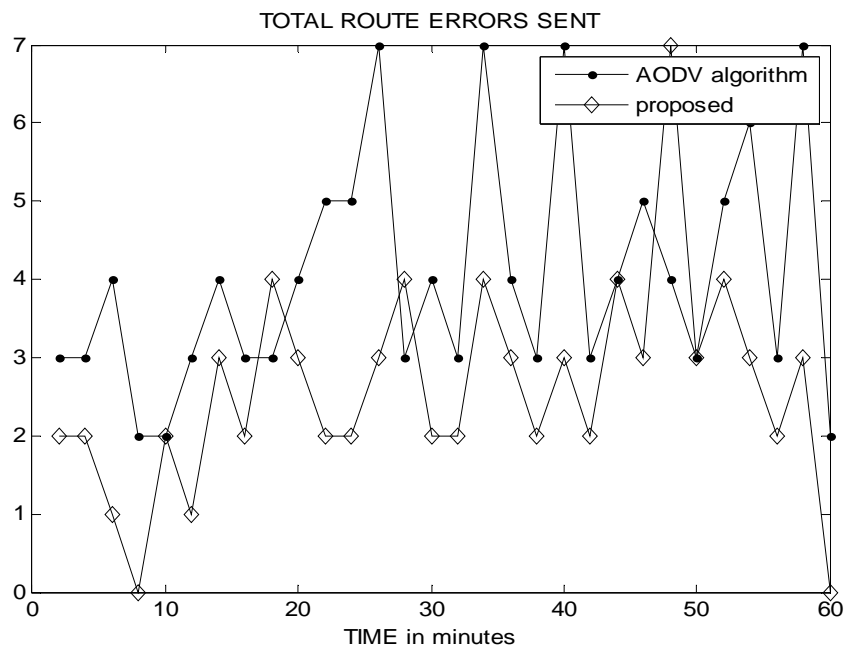


Fig. 3. Total Route Errors Sent

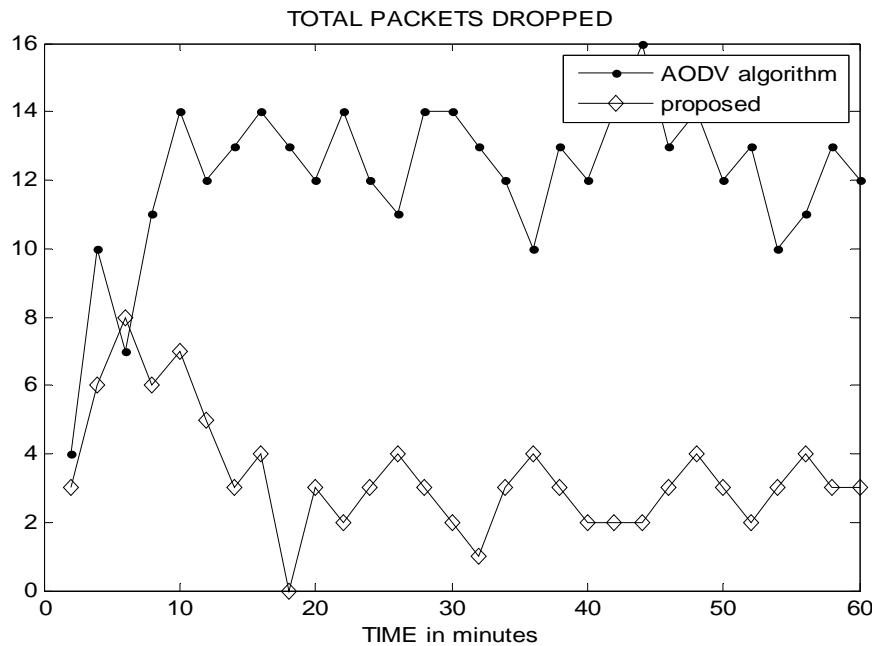


Fig. 4. Total Packets Dropped

VII. CONCLUSION

In this paper, we have proposed a new routing algorithm (DRCF), which uses the concept of CONTROLLED flooding and proxy setup. We have experimentally verified its performance with AODV and have shown that the DRCF consistently performs better than AODV with respect to two performance criteria.

As future work, we plan to test the performance of our algorithm on more complex networks. Our algorithm was tested using simulation. It would be interesting to see how our algorithm would perform on real networks under real traffic conditions.

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