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Improved Handover Mechanisms to Reduce Packet Forwarding in LTE-Advanced Using Single Poll Technique

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Abstract— **In a packet switched wireless communication system such as in the Third Generation Partnership Project (3GPP) Long term Evolution (LTE), the data packets are forwarded between base stations (BSs) during handover over the backhaul. The Packet Data Convergence Protocol (PDCP) of the source base station (BS) is responsible for forwarding the data packets to the target BS. This paper gives the analysis of earlier approaches to efficient data transfer among BSs during handover and gives two new approaches for efficient data transfer to overcome the drawbacks of the previous approach. Learning that frequent User Equipment (UE) polling causes too much load on uplink network, it is suggested that a single poll to UE on handover request is sufficient to transfer data efficiently with one poll delay time. Using fragmentation and reassembly and sequence numbering concept of IP we can even cut the single poll delay.**

Keywords— **Fragmentation and reassembly, Handover, Packet forwarding, Packet Data Convergence Protocol, Radio Link Control, UE polling.**

I. INTRODUCTION

Increasing demand for Mobile Internet in the recent past has provoked 3G and LTE operators to think of new approaches to improve Radio Access Network (RAN). In a hierarchical telecommunications network the backhaul part of the network comprises the intermediate links between the backbone network and the small sub networks at the “edge” of the entire hierarchical network. As a result of reducing cell size providing high-capacity backhaul is an emerging challenge. Hence, the cost of the backhaul network becomes a main burden on operators, and the requirement of reducing the backhaul cost is raised in Third Generation Partnership Project (3GPP) and Next Generation Mobile Networks Alliance (NGMN).

Packet-switched wireless communication system such as in the 3GPP Long Term Evolution (LTE) does not support soft handover. In LTE, at each handover the user context, including user plane packets and control plane context are relocated from the source BS to the target BS over the backhaul. Here user plane packet refers to data packets transferred from source to target and control plane context refers to control signals used in data transferring. The Packet Data Convergence Protocol (PDCP) of the source base station (BS) is responsible for forwarding the data packets to the target BS. The forwarded data is finally sent to the User Equipment (UE) by the target BS on the handover completion. The mechanism for handling the packet forwarding is specified in the 3GPPLTE specification [1] – [3], during which all the unacknowledged Packet Data Convergence Protocol (PDCP) Service Data Units (SDUs) is sent from the source BS to the target BS. Out of these forwarded PDCP SDUs, many will be discarded by the target BS, as the UE has already received some of these PDCP SDUs, a fact which could be indicated in a PDCP Status report sent by UE to its target BS. If the PDCP Status report is not sent by the UE, then PDCP SDUs will be sent from the target BS to the UE. The UE may discard these SDUs, if it has already received them from the source BS [5].

It is proposed that UE sends Radio Link Control (RLC) Status Report (SR) along with Measurement Report (MR) in [6] & [7]. Similarly, in [8], the authors propose that UE sends PDCP status report along with measurement report. Both of these status reports will enable source BS to have updated information about what UE has received, and thereby forward just the missing data to the target BS. In [4], the author proposes frequent UE polling which keeps most accurate ACK for transferred data from UE. The drawback of [6], [7] is the requirement of supporting inter-layer messages in 3GPPLTE standard. The drawback of [4] is frequent polling increases the load on the uplink of the backhaul network. In this paper two solutions have been proposed. The first solution in which rather than having frequent polling it is suggested that a single poll on handover request and transfer data to target BS from source BS based on the single poll report. Second solution in which it is proposed that use of fragmentation and reassembly and sequence numbering concept of IP to efficiently transfer data from source BS to destination BS.

II. DATA FORWARDING

Data forwarding is specified in 3GPP LTE specifications [1] – [3] as depicted in the Fig. 1. During the ongoing handover, the PDCP of a BS performs data forwarding over the X2 interface. The source BS forwards all unacknowledged PDCP SDUs to the target Base Station. The PDCP and RLC protocols are used to make sure lossless handover functionality. In the case when handover is not ongoing, each PDCP protocol data unit (PDU) is given to RLC, for transmission. The RLC acknowledged mode functions so that each RLC PDU sent by the source BS must be acknowledged by the RLC receiver at UE.

The UE RLC should send an RLC status report to the BS RLC, with positive or negative acknowledgments (ACKs)

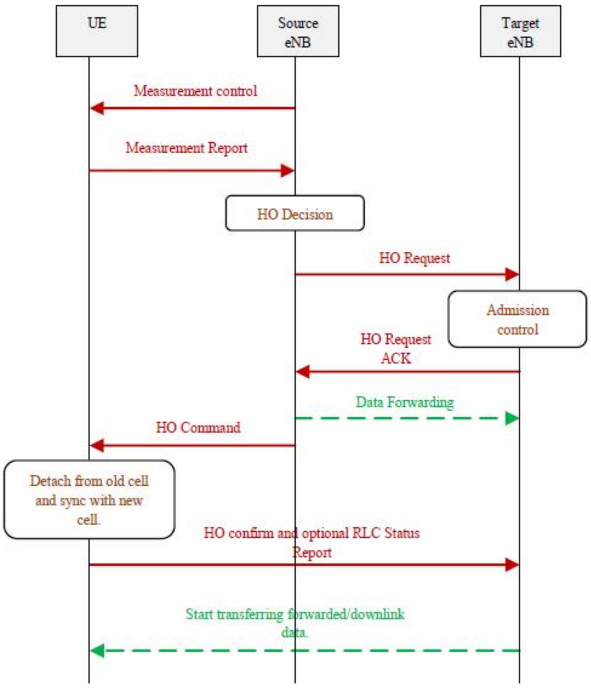

Fig.1. Intra LTE handover with data forwarding

for each RLC PDU, on either receiving RLC poll request or on expiry of the t-Status Prohibit timer with reception failure of an RLC data PDU. If the t-Status Prohibit timer is running, the RLC status report is sent upon the expiry of the timer.

Based on the last received RLC status report sent by the UE, the RLC at the source BS has information about what RLC PDU the UE has received and what it has not received. The problem with data forwarding mechanism at a BS is the dependency on the last received status report from the UE. As the status report received from UE gets older higher the amount of data to be forwarded from the source to target BS. As a result, many of the forwarded PDCP SDUs to the target BS have been already successfully received at the UE, and so are either dropped at the target BS or at the UE. This results in an inefficient data forwarding mechanism between the source BS and the target BS, which unnecessarily increases the load on the X2 interface connecting the two BSs and on the air interface between the target BS and the UE.

III. Existing Techniques To Reduce Amount Of Data Forwarding

Few techniques have been already proposed to reduce the data forwarding they are listed below:

1) Send RLC status report along with measurement report [6], [7]: In this technique, the UE sends an RLC status report along with the Measurement Report (MR) in the Up Link (UL) to the source BS. The RLC status report will enable source BS to have the updated information about the missing RLC PDUs the UE has not received. The problem with the suggested solution is that MR is sent by the UE Radio Resource Control (RRC), whereas the RLC status report is sent by the UE RLC. This means that when the UE RRC is sending the MR, which has a higher chance of triggering the handover, the UE RRC also needs to inform the UE RLC to send the RLC status report. The 3GPP LTE standard does not support and accept such inter-layer messages (in this case between RRC and RLC).

2) Send PDCP status report to source or target BS during handover [8]: In this technique, the UE sends the PDCP status report to the source or the target BS during the handover. Based on the PDCP status report, the source BS needs to forward only the unacknowledged PDCP SDUs to the target BS. The problem with this solution is it requires changes to the 3GPP LTE specifications of RCC and PDCP [2], and has so far not been accepted to be part of the specification.

3) Increase the UE polling frequency based on the DL data rate [4]: In this technique author says source BS will poll the UE more often, when the UE specific DL data rate is high and it will poll the UE less often, during the lower DL data rate. The problem with this solution is that it increases the load on Uplink network. As the frequency of polling increases the UE has to send the RLC SR frequently and the load on the UL increases. Moreover, along with change in frequency, the source BS should also configure the UEs t-Status Prohibit timer in such a way that it allows the UE to send the RLC status report. The t-Status Prohibit timer is used by the UEs receiving side of an AM RLC entity in order to prohibit the transmission of the RLC status PDUs.

IV. Proposed Techniques To Reduce Amount Of Data Forwarding

This paper proposes the method for efficient data forwarding and reduces the load on UL network. This paper proposes two solutions. First is by stopping frequent polling and having one single poll on receiving of MR from UE. Second is by using Fragmentation and reassembly and sequence numbering technique used in IP.

1) Single poll on receiving of MR from UE: According to the author in [4] we can reduce data forwarded from source BS to target BS during the handover process by frequently polling the UE for ACK on received data. As the polling rate increases the source will have up to date report on data transfer and when Handover has to take place the only those data packets which are not acknowledged by UE can be transferred.

But limitation is that it increases the load on UL network and there might be some data packets in the air, which is not acknowledged by UE and that data might also be transferred which is of no use to UE or target BS. So to overcome these two limitations, we can keep the normal polling frequency and have one additional poll as and when the MR is received from the UE and HO is about to start. As we receive the MR we stop Downlink (DL) data transfer and poll the UE for Status Report (SR) and based on the received SR source BS can only transfer un-received data packets to target BS. But this cause delay of one poll in the network. This technique is depicted in Fig. 2.

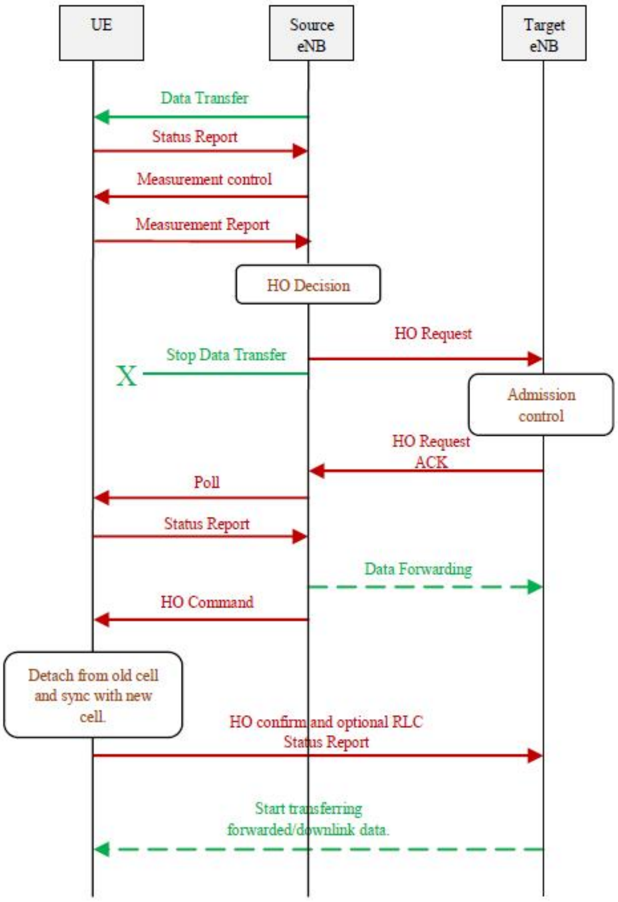

Fig.2. Single poll handover with data transfer

2) Fragmentation and reassembly and sequence numbering technique: one more approach to reduce the data transfer between BS during HO can be using fragmentation and reassembly and sequence numbering concept of TCP/IP. Internet Protocol (IP) takes care of data packets fragmentation based on Maximum Transmission Unit (MTU) i.e. DL data sent to UE is fragmented into particular size based on MTU and it is sent packet by packet. In our approach we propose to add an additional sequence number to the data packets which helps in reassembly in the UE.

Now when the source BS receives MR it can stop data transfer to UE and start data forwarding to target BS. Here Source BS can forward only those data to target BS which is not transferred to UE without waiting for SR from UE. Once the source BS receives the SR from UE if there is NACK for data packet source BS will now forward those unacknowledged data packets to target BS and then target BS can transfer those data to UE and UE reassembles those data packets based on sequence number of the data packet.

V. Simulation And Results

Simulation for first solution is carried out in NS2 considering the LTE environment simulation parameters defined in [1] [9] [10]. In this simulation file of size 1GB, 2GB, and 3GB are transferred from serving gateway to UE. The used traffic model is FTP, with a fixed file size. The FTP traffic model is selected instead of web browsing, as FTP gives more data to be forwarded during handover.

According to the 3GPP LTE specification, all the PDCP SDUs that have not been ACKed by the lower layer are forwarded to the target BS from the source BS. In this simulation source BS polls the UE for status report on receiving MR from UE and stops data transfer to UE. When SR is received from UE it forwards data from source BS to target BS through X2 interface.

TABLE I
LTE ENVIRONMENT SIMULATION PARAMETERS

Parameter	Value
Transmit time interval (TTI)	1 ms
Measurement report delay	0.03 s
Handover interruption delay	0.03 s
Round trip delay (FTP server and BS)	0.02 s
Path Switch Delay	0.01 s
X2 interface delay	0 s

Here simulation for three scenarios and three file sizes is carried out and then the time taken to transfer the data and data forwarded through X2 interface is compared.

Three scenarios considered in simulation:

(i) Data transfer from serving gateway to UE without handover.

(ii) Data transfer from serving gateway to UE with handover considering existing technology.

(iii) Data transfer from serving gateway to UE with handover considering our approach.

Results obtained from the simulation of all three scenarios are specified in TABLE II.

TABLE II
SIMULATION RESULTS

Scenario	File Size	Time	Data forwarded
Without handover	1GB	9.4 s	-
	2GB	18.53 s	-
	4GB	36.5 s	-
Existing technology	1GB	9.49 s	90.4 Mb
	2GB	18.63 s	73.3 Mb
	4GB	36.6 s	85.73 Mb
New approach	1GB	9.515 s	53.6 Mb
	2GB	18.654 s	49.2 Mb
	4GB	36.627	56.9 Mb

Based on the obtained results graph has been plot to see the comparison between different approaches on the basis of data forwarding.

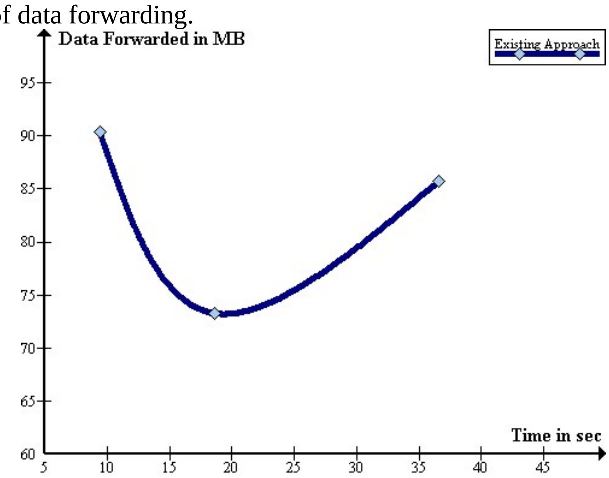

Fig. 3 Graph for existing approach

Graph in figure 3 shows time taken and data forwarded in existing system for three different file sizes like 1GB, 2GB and 4GB. It is plotted for data forwarded against time taken. From the graph we can see that 1GB file is transferred in 9.49 sec with 90.4Mb forwarded data through X2 interface. Similarly 2GB file is transferred in 18.63 sec with 73.3Mb forwarded data through X2 interface. 4GB file is transferred in 36.6 sec with 85.73 forwarded data through X2 interface. So from the above data values average time taken is 21.5 sec and average data forwarded is 83.14 Mb.

Graph in figure 4 shows time taken and data forwarded in new system for three different file sizes. It is plotted for data forwarded against time taken. From the graph we can see that 1GB file is transferred in 9.515 sec with 53.6Mb forwarded data through X2 interface. Similarly 2GB file is transferred in 18.654 sec with 49.2Mb forwarded data through X2 interface. 4GB file is transferred in 36.627 sec with 56.9Mb forwarded data through X2 interface. So from the above data values average time taken is 21.6 sec and average data forwarded is 53.23Mb.

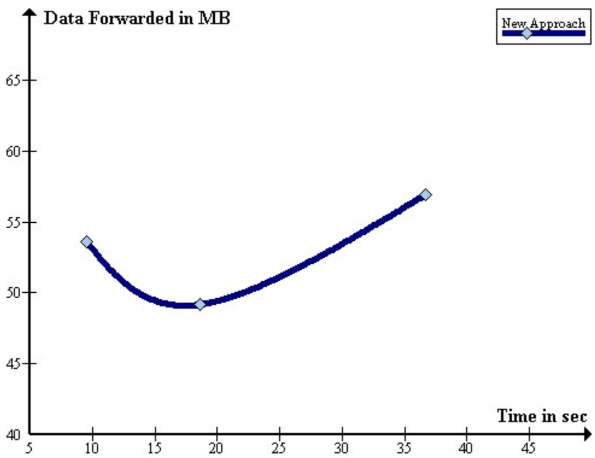

Fig.4 Graph for new approach

From the above results we can notice that there is approximately 0.0253s delay in data transfer, but there is considerably less data forwarded through X2 interface. On an average only 29.9Mb of data is forwarded. It is almost 60% reduced in forwarded data.

With the second solution even the delay of 0.0253 s can be removed, but it requires modifications in serving gateway such that it has to add new mechanisms to number the fragmented packets. So we can have our first solution as the better solution to forward data efficiently from source BS to target BS.

VI. CONCLUSIONS

In LTE communication system data is forwarded from source BS to target BS during HO process through backhaul (X 2 interfaces). The mechanism for handling the packet forwarding is specified in the Third Generation Partnership Project (3GPP) LTE specifications. This paper proposes two solutions to handle data forwarding efficiently by reducing the amount of data forwarded. Here paper proposes the LTE network to poll the UE on receiving MR from the UE for SR. Based on the SR only those data packets which are not ACKed are forwarded from source BS to target BS. Based on the simulation results this approach is proved to be 1.5 times more efficient than existing approach in terms of data forwarding.

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