2011 Eighth IEEE International Conference on Mobile Ad-Hoc and Sensor Systems

Power Efficient High Quality Multimedia Multicast in LTE Wireless Networks

Ouldooz Baghban Karimi, Jiangchuan Liu
School of Computing Science
Simon Fraser University
Burnaby, BC, Canada
email: oba2@su.ca, jclilu@cs.sfu.ca

***Abstract*—We examine power-efficient high-quality scalable video streaming in LTE networks through its eMBMS service. We consider scalable video streaming and download services offered by eMBMS service over LTE networks. We propose an effective and practical solution to jointly optimize user experience and power consumption in both UE and eNodeB. To perform power efficient multimedia transmission in LTE networks, we face three key trade-offs: (1) maximizing energy saving vs. minimizing delay, (2) maximizing sleep time vs. minimizing lost packets, (3) maximizing quality of video vs. minimizing unnecessary video transmissions. We provide a balanced solution that addresses the trade-off by including user preference. Our simulation results indicate 5% to 18% improvement in base station power consumption and 13% to 25% improvement in UE power conservation chances. The provided solution also decreases the transmitted data in the network while preserving the user perceived quality of the video.**

Keywords- Cellular networks; LTE; multimedia; multicast; power efficiency

I. Introduction

Evolved multimedia broadcast and multicast services (eMBMS) [1] deliver multimedia multicast streaming and download services in the long term evolution (LTE) networks. Although power and spectral efficient, power efficient high-quality multimedia multicast in eMBMS is a challenge. As a multicast system with uplink feedback, the eMBMS performance is limited by the capacity of the poor receivers. This is because multicast systems choose modulation and coding scheme (MCS), and multicast transmission power based on the capacity of the poor receivers. MCS decides the transmission rate. Therefore, decided by the poor receivers, it prevents the users with higher capacity to enjoy higher reception rates. Naive power settings also increase transmission power to better cover the poor nodes. This results in increased power consumption and interference.

There are two different categories of solutions trying to alleviate power consumption in high-quality multimedia multicast over wireless networks. First, transmission of layered video to improve quality for users with better reception. Base layer is sent in low rate, with high transmission power to be available to all users in the cell. Enhancement layers are coded in higher rates and transmitted with lower power. This will decrease power consumption and increase perceived quality for receivers with better signal quality [2].

Second set of solutions are power-efficient multicast solutions. These solutions range from multicast beamforming in physical layer [3] [4], and scheduling in MAC layer [4] [5], to cooperative and opportunistic routing in network layer [6]. Multicast beamforming solutions, work on efficient use of the spectrum by steering power in the directions of multicast subscribers [7] [8]. This will minimize leakage in other directions [9] [3]. However, feasibility is the key concern in beamforming context due to power or mutual interference limitations. Using effective scheduling metrics [10] and efficient multicast scheduling mechanisms [11] are also known solutions to alleviate the problem.

We consider the problem of power-efficient high-throughput scalable video multicast in LTE networks. We try to jointly optimize the user perceived quality of scalable video multicast, and power consumption in both eNodeB and user equipment (UE). Our problem is to decide the multicast groups, layers of multimedia for each group and transmission rates for them. The higher the transmission rates, the lower the sleep mode power conservation chances, and the higher the eNodeB transmission power. Therefore, we try to reduce redundant data transmission to enhance power usage in our system without degrading the user perceived quality.

II. Power Efficient SVC Multicast

Our power efficient SVC multicast algorithm is provided in three steps: grouping, channel assignment, and scheduling. The first step, grouping, is based on four different factors: (1) multicast sources a user is subscribed to, (2) requested quality of video, (3) user placing, and (4) availability of LTE femto cells in a user's area. While the three first grouping factors facilitate multicast and power setting decisions, availability of femto-cells provides chances of delegating the multicast to the femto cell base stations to eliminate the need to multicast.

We define $g_m = g_{d,\theta}^{v,j}$, a group subscribed to multicast source v, requesting video quality enhancement layers up to layer j, with average distance d and angle θ from the base station. θ starts from the east as 0, measured in the counterclockwise direction. m is the unique group identifier. While d facilitates power adjustment for a multicast group, θ facilitates the beamforming decisions based on number of antennas available in the base station. There are N_n users in G_n groups in each cell n with N_m members in each group. There are specific

978-0-7695-4469-4/11 $26.00 © 2011 IEEE
DOI 10.1109/MASS.2011.132

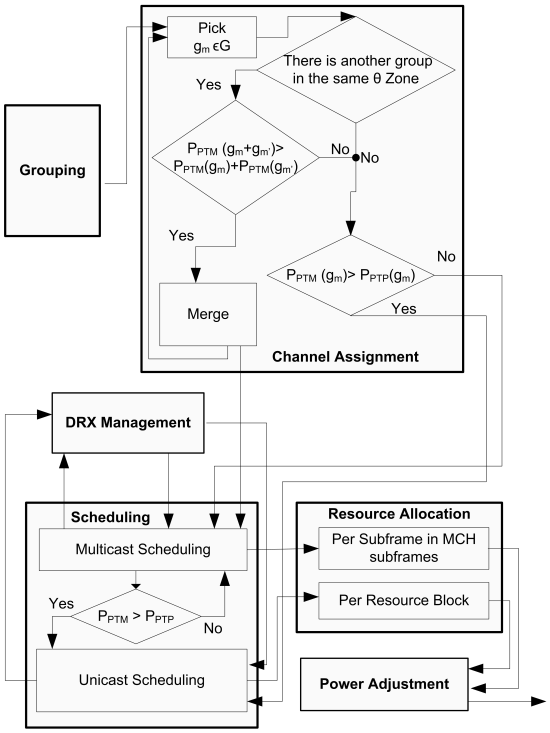

Fig. 1. Block diagram of solution components and their relations

properties to the specified groups. First, users can be member of different layer groups: $N_n \leq \sum_{m=1}^{G_n} N_m \leq L_v \times N_n$, where L_v shows the number of layers of video for the source v. Second, with the same θ and distance, the group with higher resolution request can contain the members of lower resolution groups: $g_{d,\theta}^{v,j} \cap g_{d,\theta}^{v,j'} = g_{d,\theta}^{v,j} \, \forall j' \geq j$. This is used to merge and eliminate some groups later in the channel assignment step.

As the initialization of grouping algorithm, we group the nodes in v different groups based on the different videocast sources they are subscribed to. Note that a node could be subscribed to more than one multicast source at the same time, therefore, a node may be in different groups with different v values. This may be used when a user is downloading and streaming at the same time. Then, we apply position constraints of d and θ for grouping on each video subscription group. As the final tasks of the grouping step, we bring into account the cooperative possibility and availability of femto cells and distribute the nodes within each cluster among the groups of the same distance but with different requested layers of video. With the high number of users in an LTE cell and limited number of popular multicast sources, the probability that our grouping algorithm will result in trivial one-user grouping is low, regardless of rough clustering constraints.

In the second step of our algorithm, channel assignment, we assign bearers and channels for transmission of multicast data to each group of users. This assignment is based on the power efficiency calculations done separately for each group of users. We calculate the power needed to send a certain layer of video in point to multipoint (PTM) transmission over multicast channel(MCH), $P_{PTM}(g_{d,\theta}^{v,j})$, and the power needed to send the same data using point to point (PTP) wireless transfer shared data channel(SDCH) among eNodeB and each of these nodes, $P_{PTP}(g_{d,\theta}^{v,j})$:

$$P_{P2P}(g_m = g_{d,\theta}^{v,j}) = N_m \times P_{SCH}(d, \theta, \phi_j^v)$$
$$P_{P2M}(g_m = g_{d,\theta}^{v,j}) = P_{MCH}(d, \theta, \phi_j^v)$$

The power consumption values are calculated separately for each layer $j \in L_v$ for each group. If eNodeB decides that multicast channel is the efficient medium to transmit data to an specific group, all the groups with the lower enhancement layers of the same videocast closer to the eNodeB with the same angle will be updated to use the multicast channel. In this case, channel assignment algorithm will merge those groups over $j \in L_v$ parameter if the power needed to send the extra layers of video is negligible for users not requesting it. Otherwise, the decisions are made for each group separately. This is an example of merge decision we discussed earlier.

The next step in our algorithm is scheduling the video data and allocating resource blocks for burst transmissions for each layer of video over assigned channels. We have to decide (1) which group of the users should be served next, (2) which video resource should be sent to the selected group, and (3) which layer of requested video should be sent first. We decide on the group to be served based on two factors: average channel quality indicator (CQI) values for the users of the group, and fairness among the groups. This is to preserve fairness and achieve high throughput of the wireless medium in the mean time. Note that in our mechanism, there is no feedback from the users in the multicast mode of LTE. Therefore, the CQI values should be attained and registered from unicast transmissions of the same users. This is facilitated by coupled transmission of unicast and multicast.

Next, the multicast source to be scheduled is selected for the group based on weighted round robin (WRR) on average criticality of a source, and layer of the selected source is chosen based on the summation of criticality values over the served group of nodes. We define criticality variable, $C_i^{v,j}$, as indicator of importance of each layer j of video v for a certain user i in a cell. The criticality values sum up to 1 over the layers of the same source, with higher criticality values for more important layers of multimedia.

After scheduling the packets, we perform RB and subframe allocation. We use both PTP and PTM bearers. Therefore, we should schedule packets for two different purposes, multicast and unicast. There are also some multicast packets that might be decided to be sent unicast. Those are also scheduled with unicast downlink scheduler. The data reception, sleep and awake times of each UE is decided in scheduling and RB allocation step in eNodeB, and transferred to the user.

Transmission rate for each group is then calculated based on MCS. Higher coding rates are used for enhancement layers. The last step of the algorithm assigns the transmission power to each multicast group. After scheduling the packets for each

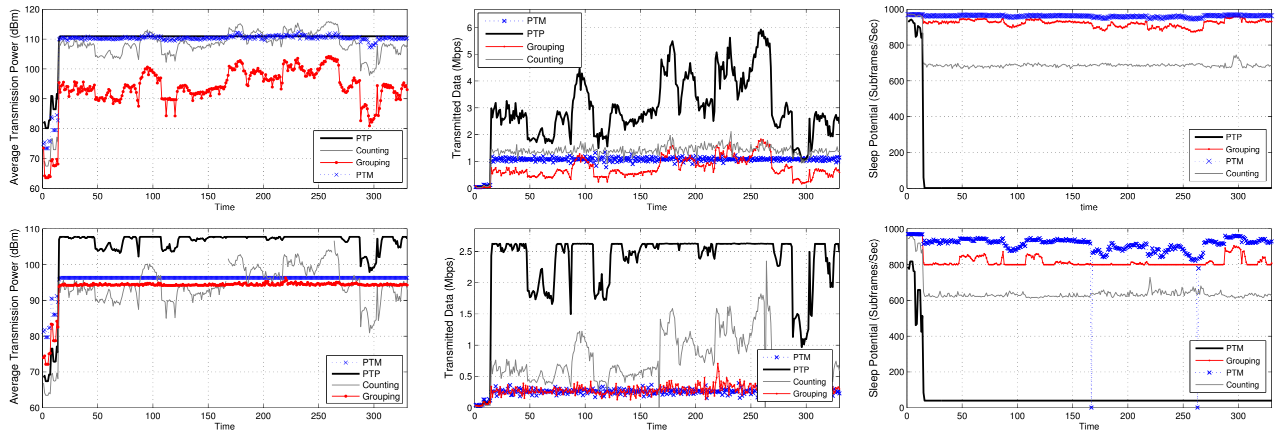

Fig. 2. (a)Average Transmission Power (Top: Bandwidth=20MHz, Bottom: Bandwidth=5MHz), (b)Transmitted Data (Top: Bandwidth=20MHz, Bottom: Bandwidth=5MHz), (c) Sleep Mode Chances (Top: Bandwidth=20MHz, Bottom: Bandwidth=5MHz)

group, assignment of transmission power to transmit the packet based on the assigned value happens in the physical layer.

III. Performance Evaluation

We used LTE-Sim [12], an open source system level implementation of LTE, as our simulation software. We have implemented the standard MBMS service as an addition to this open source tool. To our knowledge, this is the first complete implementation for MBMS among all open-source LTE simulation tools. Our video sources is Sony Demo coarse grained SVC trace file in HD, 30 frames/sec from video trace library. Four layers of video are sent in separate streams to users. The criticality values are mapped to users' request for these layers of video quality.

We present a set of our preliminary results as compared to unicast-only transmission, basic MBMS, and counting algorithm. In MBMS, multicast packets are send via PTM bearers and the MCH Channel. The counting algorithm decides on using the PTM or PTP bearers, i.e. MCH or DSCH channels, for multicast based on the number of receivers of a multicast source. In figures, PTM shows the basic MBMS implementation and PTP shows the unicast-only transmission. This choice is based on the fact that the counting method is currently used in the MBMS standards for deciding to use PTP or PTM bearers. PTM and PTP transmission also show the two extreme sides of low power consumption in PTP versus low redundant data transmission and low delay in PTM.

Figure 2 shows the transmission power, total transmitted data and the sleep mode chances. Considerably lower than the PTP and PTM methods, the average transmission power is more stable with average over the video duration period lower compared to the counting method. The transmitted data is considerably lower than the PTP and counting schemes and mildly higher than the PTM method which is a negligible cost for achieving substantial lower power consumption. The enhancement in sleep mode chances is substantial compared to counting and PTP method and comparable to PTM.

IV. Conclusion

We presented power efficient SVC video multicast over LTE wireless cellular networks. The enhancements of the provided grouping solution includes eNodeB power conservation and providing DRX sleep mode opportunities for UE power efficiency. These enhancement are gained with a mild traffic surge in the network compared to PTM. We are currently planning on extending the simulation results to include more realistic and comprehensive wireless cell situations. In addition, we envision the analysis and theoretical proof of maximum attainable gain of the provided algorithms for future work.

References

[1] L. Song and J. Shen, *Evolved Cellular Network Planning and Optimization for UMTS and LTE*. MIT, Cambridge: PhD Dissertation, 2002.
[2] T. Schierl, T. Stockhammer, and T. Wiegand, "Mobile video transmission using scalable video coding," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 17, no. 9, pp. 1204 –1217, September 2007.
[3] E. Karipidis, N. Sidiropoulos, and Z. Luo, "Quality of service and max-min fair transmit beamforming to multiple co-channel multicast groups," *IEEE Trans. on Signal Processing*, vol. 56, no. 3, pp. 1268–1279, 2008.
[4] C. Suh and J. Mo, "Resource allocation for multicast services in multicarrier wireless communications," *IEEE Trans. on Wireless Communications*, vol. 7, no. 1, pp. 27–31, 2008.
[5] H. Won, H. Cai, K. Guo, A. Netravali, I. Rhee, and K. Sabnani, "Multicast scheduling in cellular data networks," *IEEE Trans. on Wireless Communications*, vol. 8, no. 9, pp. 4540–4549, 2009.
[6] T. Low, M. Pun, Y. Hong, and C. Kuo, "Optimized opportunistic multicast scheduling (oms) over wireless cellular networks," *IEEE Trans. on Wireless Communications*, vol. 9, no. 2, pp. 791–801, 2010.
[7] M. Lopez, *Multiplexing, Scheduling, and Multicasting Strategies for Antenna Arrays in Wireless Networks*. CRC Press, 2010.
[8] N. Sidiropoulos and T. Davidson, "Broadcasting with channel state information," *IEEE Transactions on Broadcasting*, vol. 53, no. 1, pp. 235–245, 2007.
[9] N. Sidiropoulos, T. Davidson, and Z. Luo, "Transmit beamforming for physical layer multicasting," *IEEE Transactions on Signal Processing*, vol. 54, no. 6, pp. 2239–2251, August 2006.
[10] V. Vukadinovic and G. Dan, "Multicast scheduling for scalable video streaming in wireless networks," in *MMSys*. ACM, 2010, pp. 77–88.
[11] W. Ge, J. Zhang, and S. Shen, "A cross-layer design approach to multicast in wireless networks," *IEEE Trans. on Wireless Communications*, vol. 6, no. 3, pp. 1063–1071, 2007.
[12] G. Piro, L. A. Grieco, G. Boggia, F. Capozzi, and P. Camarda, "Simulating lte cellular systems: an open source framework," *IEEE Transactions on Vehicular Technology*, 2010.