Impact of Variable Network Load on Group Based Video Multicast Scheme over the HSDPA Network

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Abstract— This paper examines the effect of cell loadings on the performance of a group based multicast algorithm implemented on the HSDPA air interface. The group based multicast scheme could offer higher QoS and capacity in a HSDPA network. However, the performance of the multicast algorithm could be affected by neighboring cell loadings. In order to compensate the variable SINR conditions caused by the variation in neighboring cell loading it is necessary to optimize the group switching algorithm to maintain high QoS in a cell and to minimize the uplink feedback traffic. The paper presents simulation results showing the effects of cell loading on the performance of the group based multicasting scheme. An OPNET based multi-cell simulation model has been used to obtain the results.

Keywords—component; Multicasting, Group Transmission, HSDPA, Variable cell loading.

I. INTRODUCTION

Multimedia services provision over wireless networks has been an active area of research for the wireless networking community. The demand of different type of video applications such as live TV, Video-on-demand, Video conferencing are increasing at a very fast rate. Such an increase in demand of high data rate applications introduces capacity constraint on some networks. At the same time with the increasing the terminal capabilities it is now expected that users may be able to experience high quality video on their handheld equipments while on the move. The legacy UMTS network can support video transmissions using its *point-to-point (p-t-p) Dedicated Channel (DCH)* or the *point-to-multipoint (p-t-m) Forward Access Channel (FACH)*. The p-t-p mode is more suitable for small number of users supporting unicast services whereas the p-t-m mode is more suitable for large number of users using multicast/broadcast services. To support Multimedia Broadcast Multicast Services (MBMS), which is part of the 3GPP Rel. 6 standard, macro diversity architecture was proposed where combining transmissions of the same content from multiple base stations could provide a significant diversity gain. The macro diversity was proposed to avoid relaying feedback from users which would consume a large amount of bandwidth on the uplink [3]. Such approach could improve the coverage area and offer a reduction of 4-6 dB transmission power compared to a single reception only. However, the main drawback of the system is the consumption of higher radio resources because the same content is transmitted via multiple Node-Bs. In our previous work [2] a

group based MBMS content delivery scheme was proposed which is based on a single Node-B solution. Using the approach multicast group receivers are separated into groups where a scalable video coder is used to transmit multimedia contents to different users in a cell capable of receiving video bit streams at a different rate. The proposed scheme is implemented on the *High Speed Downlink Packet Access (HSDPA)* standard [4]. Initial simulation results showed the our proposed scheme offers a significant improvement of service QoS over the traditional multicast architecture.

In our previous work the group based video multicast algorithm was simulated with the assumption that neighboring cells are all always fully loaded. As a result the average value of the interference from neighboring cells is assumed to be constant. It is unrealistic to assume that all neighboring cell always operating at a full load. The proposed video multicast scheme works based on *User Equipment (UE)* feedback which is transmitted in the form of *Channel Quality Indicator (CQI)* which is mapped on to the *Signal to Interference and Noise Ratio (SINR)* value directly relating to neighboring cell interferences. In this work we examine the impact of neighboring cell loading on the performance of group based video multicast scheme. The scheme requires the UEs to report their CQI to Node-B only when it falls outside the group range. This way the uplink load is reduced in the presence of a large number of UEs. Variable traffic loading in neighboring cell may cause UEs to change their groups more frequently, thereby increasing the uplink traffic as well as packet losses. In order to avoid higher packet losses it is necessary to optimize the group switching algorithm. The variable neighboring cell loading conditions forces the UEs near the cell edges to frequently switch between different groups causing some packet losses. This paper examines the effect of neighboring cell loading on the group based multicast scheme using an OPNET model. The paper introduces the optimization of the adaptive group switching algorithm to minimize the packet losses and uplink feedback traffic.

The paper is organized as follows. Section II examines the effect of variable cell loading on the HSDPA network. Section III briefly describes the group based multicast transmission scheme. Simulation model and parameters are described in the section IV. Simulation results are presented and discussed in the section V. The paper is concluded in section VI.

II. EFFECTS OF VARIABLE CELL LOADING

In a HSDPA network effect of variable inter-cell interference can significantly affect a network capacity and quality of transmissions. To calculate the received SINR of different links in a HSDPA network, a typical approach is to use an average value of the intercell interference which is calculated by using geometry factor G as shown in equation 1. The value of G could vary from -6 dB to 15 dB distributed over the cell coverage area [7] [10].

$$G = \frac{P_{own}}{P_{other} + N} \quad (1)$$

Where P_{own} is total Node-B power, P_{other} is the total interference generated by other cells and N is the thermal Noise. Keeping the thermal noise as well as cell's own power as constant, the received interference signal from neighbors can be variable due to a number of factors. For example, depending on the UE location in a cell, the received power from neighboring interfering cells will have different path loss, shadow and multipath profiles. So, the G value becomes location dependent. Other factor influencing the inter cell interference pattern is the cell loading. The HSDPA standard supports data traffic on the downlink which is bursty in nature causing each Node-B to transmit at maximum power level in some time slots whereas in other time slots no transmission is initiated. A lightly/partially loaded neighboring cell will cause less interference than a fully loaded cell. The effect of interference is more visible on UEs which are farther away from the BS and closer to the cell edge.

Reviewing relevant works in the area; in the reference [1] authors have studied the impact of network loading in the neighboring sectors. Authors showed that the strength of neighboring cell interference is a function of the network load in the neighboring cells. A scheme is presented which estimates the interference based on neighboring cell loading which shows a higher achievable system throughput. The existing method in CDMA deployments uses a pilot based SINR estimation technique which in some cases could over estimate the interference effect thus reducing a system throughput. In reference [5] other cell interference has been calculated by dividing a cell into a number of concentric circles and varying traffic loads in each cell. Increase in other cell interference is reported with the increasing traffic arrival rate and the effect is more visible in the outer circles compared to the inner ones. The reference [6] presents a model for calculating the other cell interference factor (f -Factor) which is inverse of the G factor. The model considers only one interferer along with uniform and non-uniform traffic sources. Reported results show the interference variability with the non-uniform traffic load. The model also considered the cell breathing effect.

III. GROUP BASED VIDEO MULTICAST SCHEME

The proposed group based multicast scheme supports multimedia services over the HSDPA network [2]. An HSDPA connection adaptively sets its transmission rate based on the *Channel Quality Indicator (CQI)* value obtained via the user feedback. To serve a large population of multimedia users

in a cell it is unrealistic to expect that all users can receive same data rate hence, it is plausible to assume that received data rate for different users will be different. The group based transmission scheme takes advantage of a scalable video coding technique. The H.264/AVC Standard uses the scalable video coding technique to achieve high quality output using the video compression technique. The encoder generates the coded stream into one base layer and multiple enhancement layers. By using the temporal scalability same spatial resolution with different frame rate is supported in all the layers. At a Node-B, base and multiple enhancement video layers are mapped onto HSDPA connections based on the UE reported CQI. The Node-B transmits video packets to different groups of UEs which may contain only the base layer or the base layer plus one or more enhancement layers. Each UE will receive the appropriate video content sent for its group based on its received CQI. Each group is defined by a CQI range as shown in Table I. For example, if an UE is receiving a CQI value of 10 then it will receive the content of group 2, since group 2 CQI range is CQI 8-11. If the CQI of an UE changes considerably then the UE will move to a different group and receive the appropriate content. As for example, if the CQI of a UE decreases from 10 to 6 then that UE will move from group 2 to 1. Group numbers with their respective layers, CQI range and data rates are presented in Table I.

TABLE I. Scalable Video Layers mapping to the HSDPA CQI Range

Scalable Encoded Video				HSDPA MCS	
Group No.	Layers	Resolution @ frame Rate (fps)	Data Rate Kbps	CQI Range	Data Rate Kbps
1	Base	352x288 @ 30	75.5	3-7	116.5
2	Base+E1	352x288 @ 30	256	8-11	325
3	Base+E1 +E2	352x288 @ 30	640	12-15	871
4	Base+E1 +E2+E3	352x288 @ 30	1408	16+	1782

Each user reports its measured CQI value to Node-B at the time of a call setup. The Node-B after considering the distribution of UEs based on their reported CQIs generates the optimal number of groups and range of each group. The groups are then mapped on to different HSDPA MCS (*Modulation and Coding Scheme*) as shown in Table I. This information is then passed on to all the UEs through the control channel i.e. *Downlink Shared Control Channel (DSCCH)*. Each UE is required to decode DSCCH before attempting to decode the upcoming TTI *High Speed Downlink Shared Channel (HS-DSCH)* code. Each UE will keep record of its CQI in every TTI and uses it to decode appropriate group in the upcoming TTI. Any UE receiving CQI 2 or less is considered to be in the outage. For example, a UE receives CQI 10 in the current TTI then it will decode the group 2 stream in the upcoming TTI. Since selection of group is delayed by one TTI from when the CQI is received, moving to a lower CQI group will involve loss of packet in at least one

TTI. The number of groups and each group CQI ranges are dynamically managed at Node-B with minimum required Uplink signaling. Each UE keeps track of its own CQI and once it receives a CQI which falls outside its current group range, it reports back the change to the Node-B and then switches to other group. The Node-B continuously calculates the optimal group sizes and changes the Enhancement layer mapping to suit the new group range. It is worth mentioning here that in the p-t-p HSDPA transmission there is a 3 TTI (6 msec) delay involved between when the UE experiences a CQI and when the Node-B sends a packet corresponding to that CQI [10]. As reported in [9] this delay causes a reduction in throughput even after H-ARQ correction. Our scheme on the other hand, decodes the packet based on the CQI received in the previous TTI incorporating only 2 msec delay.

The scheme uses the *Adaptive Modulation and Coding (AMC)* mechanism of the HSDPA standard at the group level rather than at the individual user level. The grouping mechanism improves the overall QoS of the system because groups with higher CQI values will not be constrained by the lower CQI UEs thus improving the total QoS as well as the coverage area. The number of groups can be optimized based on the user requirements and application data rates. The approach is scalable and requires minimum signaling on the Uplink.

IV. SIMULATION MODELING

A discrete-time event-driven simulation model was developed based on the OPNET Modeler package to analyze the performance of the proposed scheme. The transmission channel model includes path loss and shadow fading models. The path loss was modeled using COST 231 Walfisch-Ikegami Model. The shadow fading was modeled using the lognormal distribution. The *Signal to Interference and Noise Ratio (SINR)* value was calculated at the output of the receiver using equation 3.

$$SNR = \frac{P_{HS-DSCH}}{P_{own}[(1-\alpha) + G^{-1}]} \quad (2)$$

$$SINR = SF16 * SNR \quad (3)$$

Where $P_{HS-DSCH}$ is power allocated to the HS-DSCH, α is the Orthogonality factor which varies with UEs distance from Node-B [7]. $SF16$ is the constant gain from spreading factor 16. To determine CQI for respective SINR value, the CQI-SINR mapping given in equation 4 is used [8].

$$CQI = \begin{cases} [SINR + 2.5] & SINR < 6 \\ [SINR + 3.0] & 6 \leq SINR \leq 10.5 \\ [SINR + 3.5] & SINR > 10.5 \end{cases} \quad (4)$$

A total of 7 Node-Bs are simulated with one in the middle serving 72 uniformly placed UEs and 6 surrounding Node-Bs generating interference. All UEs are placed in 9 concentric circles around the Node-B starting at 100 m radius

following a circle at every 100 m and 8 UEs on each circle. All UEs remain stationary during the simulation. Two scenarios have been simulated namely High Load and Low Load. High Load refers to the probability of randomly selected 4-6 neighboring cells transmitting in any time slot where as Low Load generates interference from 1-3 random neighbors in any TTI. The intercell interference value is calculated using a 80 ms moving average window. This simulation only uses fixed predefined group CQI ranges show in Table I. Important simulation parameters are listed in Table II.

TABLE II. SIMULATION PARAMETERS

Parameter	Value
No. of Node-B	7
Antenna type	Omnidirectional
Cell Radius	933 m
BS Antenna gain + cable loss	15 dB
BS Total Transmit Power	12 W
HSDPA Used Power	7 W
Orthogonality Factor (α)	Variable [7]
Geometry Factor (G)	Interference Dependent
Maximum no. of codes	5
Simulation time	70 sec
Link adaptation Algorithm	Standard AMC
Total no. of UEs/cell	72

V. SIMULATION RESULTS

In this section we analyze various simulation results obtained using the OPNET model. The average SNR of UEs for two different loading conditions at different distance from Node-B are shown in fig 1. Results show that the effect of neighboring cell loading is more prominent at the high load situation towards the cell edge. Fig 2. shows the *Cumulative Distribution Function (CDF)* of the SNR for 3 UEs located at distances of 300, 600 and 900 m radius from Node-B. It can be observed that UEs closer to cell edge have more variation in received SNR compared to the one closer to the Node-B. Fig 2 also shows the difference in received SNR values for Low and High Load scenarios. High Load scenario received lower SNR due to higher intercell interference.

Fig 3. shows the group membership of each group for the fixed neighboring cell loading condition where interference level is constant over the operating period. As these values do not take into account the variability of neighbors interference, the membership remains content over the simulated time. The CDF of the group membership is shown in fig 4 when variable neighboring cell loading is simulated. Contrary to fixed loading scenario as shown in fig 3, the membership of first 3 groups shows the changes over the time which is due to the varying inter-cell interference pattern. The gain in terms of higher group membership can also be seen in this figure where low load scenario has a higher membership in group 3 compared to the high load

situation whereas the group 2 gets more members in high load scenario due to higher interference. This means that more users are able to achieve higher data rates for low network loading conditions.

Figure 1. Average SNR at different distance from Node-B

Figure 2. CDF of SNR for High/Low Load at 300, 600 and 900 m

Figure 3. Group Membership with Avg. G

As previously mentioned that our scheme works in a way to minimize the uplink feedback traffic generated by UEs. Each UE only report its CQI to Node-B if it falls outside its current group range. This algorithm works well in a fixed loading condition scenario because a long term average G value is used hence UEs change their groups less often which is mainly caused by shadow and multipath fading. On the other hand when we consider a variable loading condition, UEs start switching groups more frequently. This phenomenon is more visible for the UEs located beyond 500 m radius from Node-B. When a UE receives a lower CQI value that falls outside its current group range, the UE will not be able to decode the

received packet. It reports to the Node-B of its new CQI and starts decoding from the lower group in next TTI. This process introduces at least one TTI delay before the UE joins new group. This effectively means that for every group downgrade at least one packet is lost for the UE. Since the SNR of UEs are more fluctuating near the cell edge as high load 900 m UE CDF signifies in fig 2, there is some unnecessary group switching introduces by these UEs. Fig 5 shows the percentage of UEs having more than 1 % packet loss when the group change is instantaneous i.e. with one TTI delay. The UEs with higher than 1% packet loss are the ones which are located outside the 500m radius circle. In High Loading condition 33% UEs could lose up to 3% downlink packets whereas 22% UEs in the Low Loading scenario could lose packets in the same order. Fig 6 shows the average uplink feedback traffic per second generated by all the UEs for reporting their CQI. On average about 200 feedbacks are sent every second to Node-B i.e. in High Load scenario 1 UE attempts to inform Node-B of its CQI every third TTI because it is switching to another group.

Figure 4. CDF of Group Membership for High/Low Loading

To smooth out the phenomenon of unnecessary group switching and to minimize packet losses and uplink traffic, the group switching algorithm has been modified. The modification involves dividing UEs in two categories; namely the inner circle UEs and the outer circle UEs where inner circle UEs are the ones within 500 m radius from Node-B and the remaining are in outer circle. UEs will be requiring to partially restricting their group switching only when they are upgrading. In case of a group downgrade, UE reports its CQI to Node-B immediately after it falls outside the group range and starts decoding the lower group transmission from very next TTI. Group downgrading cannot be delayed or restricted because it will only result in more packets loss during the delay period. The group upgrade on the other hand does not involve a packet loss. The inner circle UEs will immediately upgrade the group once they start receiving a higher CQI. The outer circle UEs will not upgrade if they receive a CQI which is the lower boundary of higher a group e.g. a UE is currently

in group 2 for which the CQI range is 8-11, if this UE now receives CQI 12 which is the lower boundary of group 3 (12-15), it will not upgrade to the higher group. This UE is only allowed to upgrade to higher group if its newly received CQI is higher than the lower boundary CQI of next group i.e. CQI 13 or higher in this case. Fig 5 shows that for both High and Low Load Scenarios 100% UEs experience less than 1% packet loss due to the introduction of restricted group upgrade. Fig 6 shows the reduction in uplink traffic for both scenarios which is reduced by almost quarter with the modified group switching scheme. While this modification reduces the overall packet loss and uplink traffic load, the changes comes at a price of more UEs staying in lower groups and receiving lower data rate than what they are capable of receiving on the boundary of next group. This is a tradeoff between having more UEs in higher groups more often and high packet loss or few UEs in lower groups and low packet loss and reduced uplink load. Fig 7 presents a view of change in group membership pattern due to restricted group upgrade switching algorithm. Group 3 membership has decreased while group 1 and 2 gets few more members than instantaneous group change case.

Results presented in this paper clearly show that group based video multicast scheme can perform equally well when tested in a more realistic scenario of variable network loading conditions. The modified scheme serves 100% UEs with less than 1% packet loss ratio. The scheme also ensures a lightly loaded uplink while be able to serve a large population of video users.

VI. CONCLUSION AND FUTURE WORK

This paper presents the effect of network loading over the group based video multicast scheme. Considering neighboring cell loading conditions for users throughput is a more realistic scenario compared to using an average value. With the introduction of the restricted group switching algorithm the group based video multicast scheme can operate with high QoS in variable network loading conditions. Introducing UE mobility will require dynamic group management. In future we will be looking into incorporating an algorithm for dynamic group management which is needed for optimizing air resource usage while providing highest possible data rates.

Figure 5. Packet Loss % for Instantaneous and Restricted Group Change Scenarios

Figure 6. Uplink Traffic for Instantaneous and Restricted Group Change

Figure 7. Group membership for high load instantaneous and restricted group upgrade

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