

Application of Video Error Resilience Techniques for Mobile Broadcast Multicast Services (MBMS)

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Abstract

With data throughput for mobile devices constantly increasing, services such as video broadcast and multicast are becoming feasible. The 3GPP (3rd Generation Partnership Project) committee is currently working on a standard for Mobile Broadcast and Multicast services (MBMS). MBMS is expected to enable easier deployment of video and multimedia services on 3G networks. We present an overview of the standard including the proposed architecture and requirements focusing on radio aspects. We discuss the issue of video error resilience in such services that is critical to maintain consistent quality for terminals. The error resilience techniques currently used in video streaming services are not suitable for MBMS services. We analyze the error resilience techniques that are applicable within the context of MBMS standard and present our early research in this area.

1. Introduction

Wireless communication systems have experienced tremendous growth in the last decade and continue to change the way people communicate with each other. The mobile devices are getting bundled with additional features that are turning them from a communication device into an entertainment device and an informative device. With carriers rolling out 3G networks and the mobile devices with access to WLAN networks, the available bandwidth and throughput of mobile devices is increasing. With such data rates, applications such as video streaming, audio streaming and broadcast or multicast video are becoming a reality on mobile devices.

Due to mobility, the mobile handsets experience wide variety of network conditions such as fading, diversity of signal strength conditions and interference. The transmission of video during such conditions is very challenging especially with real-time requirements in a session shared by multiple users. With participants of the multicast or broadcast session experiencing diversity of network conditions, maintaining video quality is a demanding problem and requires significant research in this area.

There has been a considerable amount of research in the area of video error resilience and a plethora of techniques are available but such techniques have typically been applied to messaging or streaming or video phone type of applications [3,4,6-10]. The traditional error resilience techniques for multicasting focused on FEC or ARQ based techniques and have been applied to the internet or ATM based systems. However, MBMS introduces a new paradigm from traditional multicasting systems due to mobility, diversity of signal conditions, low power and spectrum utilization requirements of receivers.

Video broadcast or multicast services are an efficient way of providing exciting content such as video and audio to the end users. They are spectrally efficient and lower the cost of the services to the end-user.

2. MBMS Architecture and Concepts

3GPP is currently in the process of establishing a standard for MBMS. This standard is expected to be ratified in 2 to 3 years and systems compliant to the standard are expected in 3 to 5 years. The purpose of the standard is to standardize core components and interfaces in the system architecture that would eliminate ambiguity and promote synergy between network operators, content providers, terminal manufacturers and network manufacturers [1]. Streaming of live or stored video content to group of mobile devices comes under the scope of MBMS. Some of the typical applications are subscription to live sporting events, news, music videos, traffic and weather reports, and live TV content.

Figure 1 shows an example of a multicast broadcast network. It shows several components involved in providing the services and shows how the network can be configured to broadcast a variety of high bit rate services to users within the associated broadcast service area. It also provides support for authentication, service provisioning, signaling aspects such as service announcement and notification.

The broadcast service is typically free within the broadcast area whereas multicast service requires subscription. Multiple multicast groups could exist within the broad-

cast area where multiple sessions could be ongoing at the same time.

MBMS specifies transmission of data packets from single entity to multiple recipients using a common broadcast channel. This is much more efficient than IP multicast where packets are duplicated for each recipient in a broadcast or multicast group.

The functional entities to support MBMS are shown in Figure 2. The Broadcast-Multicast Service Centre (BM-SC) provides functions for MBMS user service provisioning and delivery. It may serve as an entry point for content provider MBMS transmissions, used to authorize and initiate MBMS Bearer Services and can be used to schedule and deliver MBMS transmissions. The BM-SC should be able to provide the GGSN (Gateway GPRS Support Node) with transport associated parameters such as quality-of-service and MBMS service area. It should be able to accept and retrieve content from external sources and transmit it using error resilient schemes.

The BM-SC should be able to schedule retransmissions and label each MBMS session with a unique identifier for UE (User Equipment) to distinguish the MBMS session retransmissions. For each mobile that joins the session, a context is created for each device on RAN/GERAN, Core network and the BM-SC.

In this paper, the focus is on the radio interface between mobile terminal and RAN (radio access network) where the packet loss in the network could be significant and require loss prevention, concealment, and recovery techniques to provide consistent quality.

In this paper, the focus is not on signaling aspects such as a joining or leaving a multicast session by a mobile terminal but focus on multimedia delivery during session. This paper primarily concentrates on the RAN's (Radio access network) interface with the UE. The key MBMS requirements are listed below [2]:

- MBMS does not recommend retransmissions at the link layer due to losses or upon feedback from the terminals. It however does not preclude periodic repetitions of the MBMS content based on operator or content provider scheduling of retransmissions based on feedback at the application level.
- MBMS session should provide continuous service during handover with minimal data loss.
- MBMS also requires joining an ongoing session as it would require interoperability with other services.
- MBMS does not specify QoS (Quality of Service) at the RAN layer but expect a certain level of reservation for the service.

- MBMS specifies shared dedicated resources (point to point) or common resources (point to multipoint) and is left to the operator to select connection type. This is based on downlink radio resource environment and factors such as radio resource efficiency.

Any error resilience technique deployed on the system has to conform to these requirements. Developing error resilience techniques that are spectrum efficient as well as provide a high quality of experience to the end user is a challenging problem. We have reviewed the previous work in this IP multicasting domain and believe that new research is needed to deliver reliable video services using MBMS.

3. Error resilience in Wireless Video transmission

Video communication requires a significant amount of bandwidth compared to the voice or audio communication. However, video data comprises of spatial, temporal and statistical redundancies. These redundancies are exploited in video compression techniques to reduce the bandwidth required for wireless video communication. The general techniques used in low bit rate video compression algorithms result in spatial as well as temporal dependencies that make the compressed video highly vulnerable to transmission errors.

In the current Video compression standards such as H.263+, MPEG-4 and H.264, hybrid coding techniques are used where both temporal and spatial redundancies are minimized for higher compression. In temporal prediction techniques, a frame is either coded with no other frame dependency (Intra Frame) or coded with dependency on past frame (P Frame) or coded with dependency on past and future frames (B Frame).

Depending on the framing structure, a group of pictures (GOP), contains an I frame followed by a combination of P and B frames. The frame dependencies exist among the frames within a GOP. During the transport of video packets or for any other reason, if there is loss of data, the error is propagated until an error free Intra frame is decoded (beginning of the next GOP).

The errors that occur in video communication can be roughly classified into two categories: random bit errors and erasure errors [3]. Depending on the coding methods and affected information content, the impact of random bit errors can range from negligible to objectionable. Erasure errors, on the other hand, can be caused by packet loss in packet networks. To combat such errors, the error resilience is designed where Forward error correction techniques (FEC) and ARQ strategies are used. The FEC technique uses redundancy that is used to detect and correct

ever, the amount of redundancy that is added is independent of the receiver's current signal strength conditions; it is redundant in good signal strength conditions and ineffective in very bad signal strength conditions. ARQ strategies that rely on retransmission are adaptive to the signal strength conditions however the delay is unbounded. The ARQ strategies are not recommended in multicast scenarios with a large group where there could be feedback implosion.

A combination of FEC and ARQ strategies are deployed as Hybrid ARQ techniques where during retransmission the parity packets are sent or perform retransmissions when FEC is not sufficient.

Despite the ARQ and FEC strategies, the wireless networks would experience bit errors so the video application should be error resilient to compensate or mitigate errors. The applications should minimize the impact of errors by localization and prevention of error propagation. The error concealment techniques are also crucial in the case of multicast applications where errors are unavoidable in heterogeneous networks.

An overview of video error resilience techniques is presented in [3]. Error resilient support provided in H.263+ or MPEG-4 standards is presented in [2]. Weigand et. al., focus on H.264 standard and provide a survey of wireless error resilience techniques for streaming and messaging applications [5].

A survey of error resilient techniques for multicast application for IP-based networks is reported in [6]. The paper presents algorithms that combine ARQ, FEC and local recovery techniques where the retransmissions are conducted by multicast group members or intermediate nodes in the multicast tree. With heterogeneous receivers experiencing wide-ranging error rates, multiple multicast groups are formed with analogous link conditions. Video error resilience techniques using hierarchical algorithms are proposed where transmission of I, B and P frames are sent with varying levels of FEC protection. The RTP (Real-time transport protocol) payload formats for transporting UDP packets together with RTCP (Real-time control protocol) feedback reports is also utilized in multicast networks.

Support for multicast and broadcast services in CDMA 2000 and algorithms for efficient bandwidth representation are presented in [7-8]. Some of the prior research work on error resilience for broadcast terminals focuses on increasing FEC based on the feedback statistics from the users [9]. The additional FEC protection is based on the average error rate experienced by members of the session. Also, research on proxy based error resilience is presented in [9]. However proxy requires individual retransmission based on feedback from the terminals. A comparison of different error resilience algorithms for wireless video multicasting on WLANs (Wireless Local Area networks) is reported in [10]. Novel methods for multicast and unicast real-time video streaming over wireless LANs using hybrid ARQ techniques is presented in [11]. The multicast system takes into account

the heterogeneity of receivers and uses that information to minimize the distortion experienced by each user.

However, in the literature survey we found that error resilient techniques at the video codec level are not applied to multicasting areas. Here is where we foresee some innovative research that would significantly impact the quality of video delivered over MBMS services. In the next section, we discuss the common video error resilient techniques and how they can be applied to the MBMS systems.

4. Application of video error resilience techniques for MBMS

The MBMS systems introduce a new paradigm from the traditional internet or satellite based multicasting system due to mobility. The system has to account for wide variety of receiver conditions such as handover, speed of the receiver, interference and fading. Apart from that, the required bandwidth and power should be kept low for the mobile devices.

The video error resilience techniques can be classified into the following:

- Encoder based techniques
- Decoder based techniques
- Interactive based techniques
- Proxy based techniques

The interactive and proxy based techniques where lost packets are requested by the receiving terminal for retransmission are ruled out in MBMS systems.

Despite the ARQ or FEC strategies, the wireless transmission can hardly be error free. After error correction, even if there is one error, it is declared as lost packet. Due to the heavy compression in video codec and variable length codes used for entropy coding of coefficients, a single error could render the packet undecodable.

However, some parts of the packet can still be decoded if the error can be localized. The error localization techniques are discussed in [12]. The tools that MPEG-4 standard offers for error resilience are:

- Resync markers
- RVLC (reversible variable length codes)
- Header retransmission

The resync markers are unique bit patterns that are embedded periodically within the encoded bit stream. If there are any bit errors at the received bit stream, the decoder would lose synchronization. The decoder can check for errors by taking into account the syntax of the MPEG-4 header and if the decoder detects an error, it can scan for the next resync marker. Upon detecting a valid resync marker, it can start decoding again. Without such resync markers, the packet will become useless once decoder loses the synchronization.

The property of RVLC codes is, with small coding overhead, the encoded coefficients are symmetrical and could be decoded both ways. Upon detecting an errors and jumping to the next resync marker, the decoder can start decoding backwards thereby giving an opportunity to recover the packet as much as possible.

In a multicasting session, the header retransmission is useful in multicasting or broadcasting when members can join the session during any time. It is also expected that during the joining time, they would be give the header information necessary to join the session.

When a mobile joins an existing broadcast session, there is a delay before which it can get synchronized. This delay is proportional to the frequency of I frames as determined by the system. Since I frames require more bits than P frames, the compression efficiency is inversely proportional to the frequency of I frames. If f is the frequency of the I frames and r is the frame rate of the video compression, the worst case initial delay in seconds,

$$D = (f - 1) / r$$

The application would also require more frequent transmission of I frames so as to allow the user to join the ongoing session however it would result in requiring more bandwidth. This is a design trade-off in determining the frequency of I frames. Another alternative is that during the joining time an I frame is unicast to the member. If such a scheme is devised, then the initial delay is independent of the frequency of I frames. This also requires additional synchronization signaling and system design to ensure an I frame that is being unicast matches with the current frame being broadcasted.

One other tool that is effective against error propagation is Intra block refresh technique. In this technique, a percentage of P or B frames blocks are intra coded and criterion for determining such intra block is dependent on the algorithm. Since the intra blocks do not depend on the previous frames, the distortion is limited. Typically the percentage of Intra blocks is fixed however the percentage could be varied depending on the signal strength conditions. However the intra block refresh technique is not effective in combating error propagation when I frames are less frequent.

In multicasting scenarios, using RTCP feedback reports, the quality of the link for each receiver can be determined. Based on the quality, the percentage of intra blocks can be determined. If the receivers are experiencing high error rates, the intra block percentage is increased and vice versa. This technique is effective for a smaller group of members which is the case in a cell area served by a base station. With such basis, a proxy would be integrated with the base station that handles the multicasting and has the capability to vary the intra block percentage through decoding and re-encoding video stream coming from the sender.

Since mobility is expected during session, there is typically significant packet loss during handover. If the packet loss occurs on an I frame, it would effect all the P and the B frames that predict from the I frame. In the case of P frames, the error concealment techniques could mitigate the loss however the distortion would continue to propagate until an I frame is found. These could also be managed using intra block refresh rate technique. The loss of B frames limits the loss to that particular frame and does not result in error propagation.

The RTCP feedback reports from the recipient could be reported back to the sender and based on such reports, application based retransmission of packets are allowed. However, the effectiveness of such technique depends on round trip delay between the sender and the receiver. It also requires extra bandwidth on a shared channel. In MBMS, a point to point retransmission could be applied however this is used in extreme losses such as I frame loss as it is bandwidth intensive.

Apart from the traditional multicasting / broadcasting techniques, the MBMS system requires new techniques for error resilience. Since MBMS does not allow for retransmissions, the temporary fading conditions of wireless channels could result in corruption of certain frames. Due to the frame dependency within the hybrid coding techniques, the errors propagate until an I frame is decoded. In our prior work [10], we proposed a new technique called Periodic Intra Frame based Prediction (PIFBP) in which the predicted P frames are based on the previous I frame and corruption of a P frame would not affect the next P frame. The graphical depiction of the frame structure is shown in Figure 3.

Figure 4 depicts the performance of PIFBP scheme compared with the performance of MPEG-4 Simple Profile (SP) codec during frame loss. The percentage of frames that are dropped is varied and it is clearly seen that PIFBP scheme maintains the quality whereas the MPEG-4 Simple Profile (SP) codec with varying I frame periods (VOP period), the quality degrades with increase in frame loss percentage. The foreman sequence was used for the experiments with bit rate of 128 kbps with the frame rate of 15. This technique will perform really well in Wireless multicasting scenarios due to the robust underlying structure. The I frames could be protected with additional FEC. The P frames can be given less protection as loss of P frame would not propagate.

An interesting point to note is that mobile devices are getting equipped with Local area networks such as Bluetooth and Wireless local area networks. Such devices could form an adhoc network on local area networks for error resilience purposes. The session identifier for broadcast or multicast could be used for forming the network. We are currently working on the mechanism to recover lost packets on a secondary network.

5. Conclusions.

An overview of the MBMS architecture and relevant requirements are presented. The prior art in video error resilience techniques is also described with focus on multicasting. Based on our research, the existing error resilience techniques are not enough for providing good quality on bandwidth efficient MBMS systems and new research is necessary. We also propose innovative error resilient techniques such as PIFBP, adhoc error resilience channel on a secondary network and group feedback based intra block refresh techniques.

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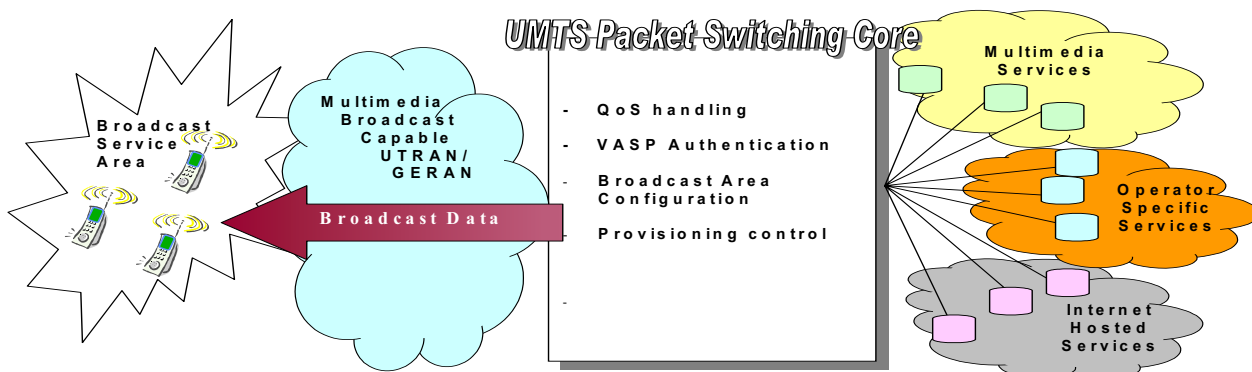


Figure 1: Example of Multicast Broadcast Mode Network

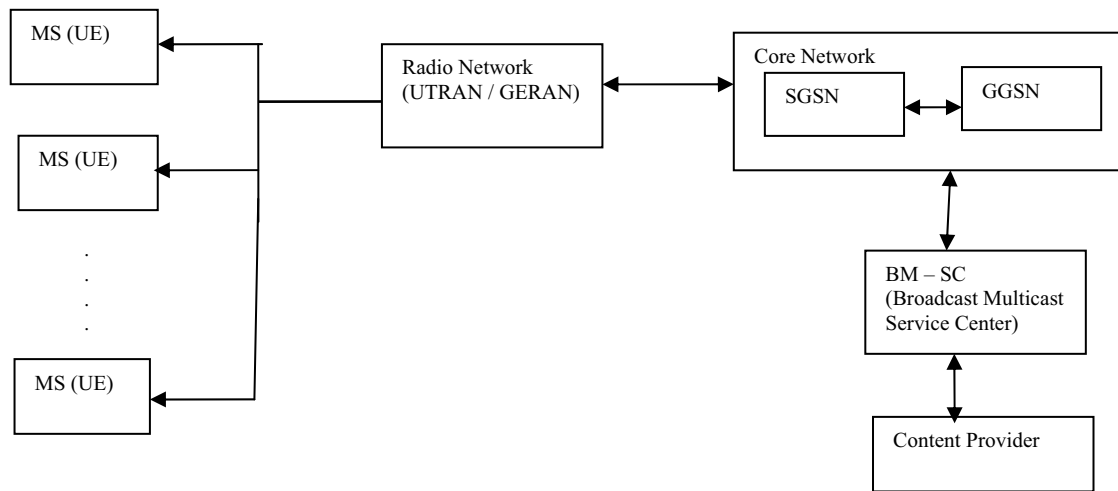


Figure 2: Architecture for MBMS service

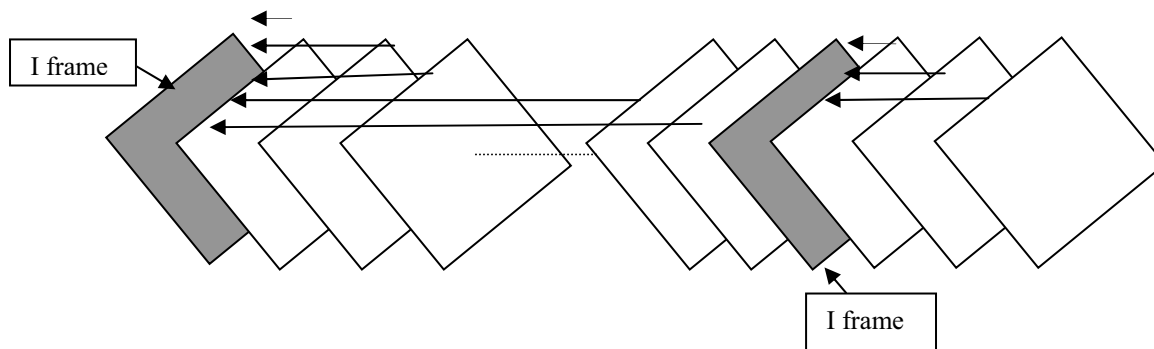


Figure 3: Periodic Intra Frame based Prediction

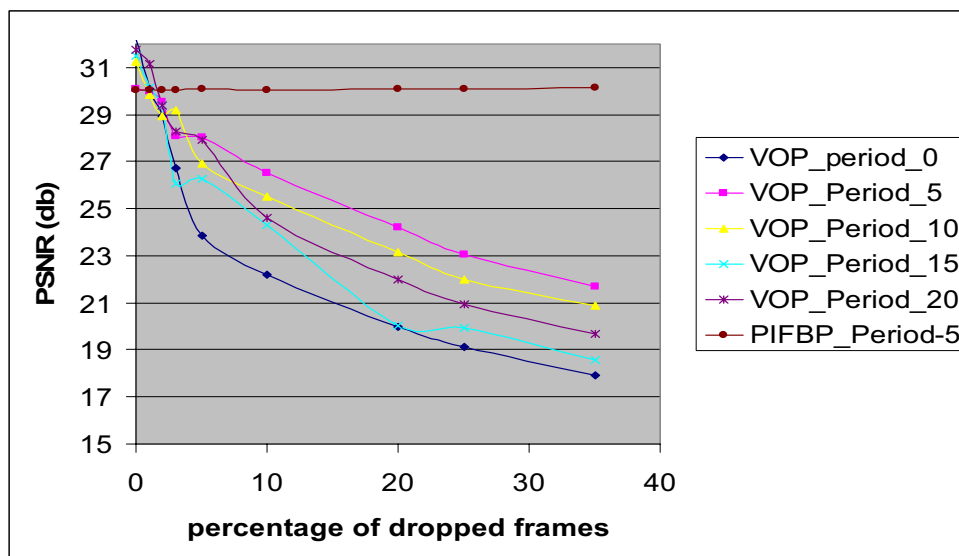


Figure 4: Performance of Inter / Intra frame coding during frame loss (Data rate = 128 kbps, fps =15 fps)