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# Trends in Multimedia Communications Over Mobile Networks

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Increasing demand for high quality multimedia services has been a driving force in the technological evolution of high bandwidth wireless/mobile communications systems and standards. The most challenging aspect is the support of higher quality video, which requires a higher bandwidth. Although the operational third generation (3G) wireless systems may be capable of handling low data rate video [1], [2], the problem is that mobile cellular technology is not ready to offer reliable real-time video services. In addition, as the proliferation of mobile video accelerates, the next generation wireless communication systems must aim at providing higher per user data rate services to support higher quality real-time audio/video services, especially as new applications, such as ubiquitous on line journalism and live citizen reporting, are emerging.

It is important to note that in mobile environments a higher per user bandwidth does not necessarily guarantee a higher video quality reception. Thus, the major technical challenges will be to cope with frequency-selectivity fading due to the use of larger bandwidths. As far as transmission at the physical layer is concerned, schemes such as OFDM (Orthogonal Frequency Division Multiplexing) and MC-CDMA (Multi Carrier-Code Division Multiplexing), which are capable of providing frequency diversity, can indeed enhance robustness to frequency selective fading.

In addition, recent technological breakthroughs in Multiple Input Multiple Output (MIMO) techniques [3], [4], i.e. providing space-time diversity, have already made a significant impact to transmission over mobile channels in terms of reliability and throughout. Needless to say, a deep fade in all the wireless channels may still erase some of the information and consequently, the use of error control coding - particularly for real-time multimedia - remains a major research topic in mobile communications.

Error control coding methods, such as error detection and error correction have been traditionally applied at the physical layer in most digital cellular communication systems (also referred to as channel coding). In the case of the IEEE 802 standard for Wireless Local Area Networks (WLAN), for instance, the physical and link layers are responsible for handling error control coding for IP packets. This includes a 16-bit CRC (cyclic redundancy check**)** error detection field at the physical layer and packet retransmissions via the MAC (Medium Access Control) sub-layer.

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However, in a packet based wireless network environment where communications may need to be integrated into the framework of the OSI **(**Open Systems Interconnection**)** model, the error control coding strategy is a challenging issue. This is mainly a consequence of the layering structure in the OSI protocol stack, where the protection against packet loss is handled separately and independently for each layer. For instance, in addition to the link and physical layers, error control coding in the form of Forward Error Correction (FEC) is also applied at the application layer. For video transmission particularly, a combination of multi-layer coding and FEC with a differing level of protection for each layer (also known as unequal error protection: UEP), has been an effective approach for transmitting video over multipath fading mobile channels [5], [6].

Nonetheless, when the channel condition is unknown and there are multiple receivers, the use of a fixed rate error control coding could be wasteful and unreliable. Recently, a new generation of rate-less codes, such as raptor codes [7], has been considered for file download in the Digital Video Broadcast for Handheld (DVB-H) standard [8]. In the raptor code, which is a category of the Fountain code, the encoder can generate as many encoded symbols as needed from a block of data on the fly. Raptor codes have the advantage over traditional fixed rate erasure codes, such as Reed-Solomon codes, for their ability to manage the overhead when channel conditions are unknown.

The flexibility and reliability of the Raptor code for UEP has been studied by a number of researchers in recent years [9], [10]. IETF RFC 5053 [11] defines procedures for generating the Raptor FEC and its application for the reliable delivery of data objects. In addition, for Digital Video Broadcast two-layer protection for real-time multimedia data has been recently proposed, where the first layer (base layer) is protected by the 1-D interleaved parity code, and the enhancement layer is produced by the Raptor code [12]. It should be noted that in this AL-FEC approach, the source packets are carried in separate RTP (Real-time Transport Protocol) streams. The next layer in the protocol stack is the transport layer. Between the two popular transport protocols, TCP and UDP (User Datagram Protocol), UDP is the preferred protocol. Nonetheless, this protocol, unlike the connection oriented TCP, is the best effort transport protocol. Since UDP cannot provide reliable packet transmission, additional error control coding may be needed to prevent any significant loss of video quality.

Indeed, further coding can be accomplished at the next lower layer in the protocol stack, which is the network layer. This layer is responsible for routing RTP/UDP/IP packets to their destinations. In the case of mobile ad-hoc networks (MANET), these autonomous networks are not quite capable of reliably distributing RTP/UDP/IP packets [13], [14]. One major obstacle is a problem with the dynamically changing network topology. This manifests itself in a frequent route change, consequently causing a potentially long delay [15]. Co-channel interference from other users is another important factor that is problematic and can severely impact the end-to-end throughout performance. While mitigating the effect of interference continues to be an active research topic, a new approach known as network coding, has recently emerged [15]. Its concept is based on performing coding operations in the interior network, rather than just being received and forwarded by the intermediate nodes (routers). By intelligently mixing

packets in multicast routing it is possible to enhance the network throughput performance. Although network coding appears to work well for wired networks, the debate on its suitability for unreliable multihop environments for real-time multimedia services is now becoming a hot research topic.

Finally it is worth noting that in contrast to fixed wireless communications, existing mobile networks are still incapable of supporting reliable, interactive, and high quality video services. This is mainly due to a number of factors, such as increasing demands for live video transmissions, bandwidth limitations, co-channel interferences, and ever-changing channel conditions. Developing methods such as space-time diversity for cooperative transmission for multihop networks is becoming the most active research topic in combating multipath fading [16], [17]. In addition, in such environments error control coding techniques still continue to play a major role in supporting high quality multimedia services for the next generation of wireless/mobile networks. As far as their deployment is concerned, the major problem is that they are separately applied within each OSI layer without any attention to the tradeoffs between overhead, latency and performance. This will involve the issue of cross layer optimization in order to maximize their efficiency in accordance with service quality requirements.

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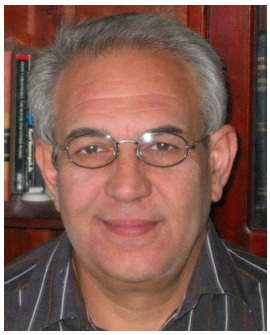

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