Joint Unicast/Multicast Mobile Video Surveillance

Laith Al-Jobouri and Martin Fleury

University of Essex, United Kingdom

Introduction

Video-surveillance networks often consist of a set of geographically dispersed cameras, views from which are fed to a control centre. However, if the surveillance network includes moving people and vehicles, both equipped with cameras, a less static architecture is required. Suppose an emergency has arisen then those recording views in their sectors and other early responders can benefit from a composite video feed that updates them on the developing situation. Apart from emergencies, one can imagine other scenarios such as news gathering and traffic congestion policing. The joint unicast/multicast video transmission system developed in the poster will also be of interest to mobile IPTV developers, as higher-quality video-on-demand can be disseminated through unicast, while multicast can benefit news and sports updates.

Surveillance architecture

For this demonstration, we have assumed mobile WiMAX technology (IEEE 802.16e with speeds up to 120 km/h). Fig. 1 shows a set of mobile stations (MSs) that record individual views. These are streamed, not necessarily simultaneously, to a co-ordination centre via a base station (BS) responsible for an urban cell approximately 1 km in diameter, Non-Line-of-Sight (NLOS) transmission is provided. At the coordination centre, the video feeds are intelligently aggregated before being multicast possibly to a further set of MSs, i.e. mobile emergency responders.

The BSs and their cells need not be adjacent or co-located, as it is possible that an intervening IP network permits a response team at another location to become aware of a developing problem. For example, if a moving crowd of football supporters is filmed at one location and fed to those monitoring a railway station some distance away. The surveillance scheme can also be extended via the WiMAX wireless mesh framework and each cell can be expanded via IEEE 802.18j, which includes relay stations (RSs) to extend coverage to within buildings or to coverage holes. The capacity of WiMAXs systems can also be upgraded to IEEE 802.16m, which specifies features enabling group communication available in other private wireless systems such as TETRA 1 & 2, including push-to-talk and pre-emptive calls and call prioritization. Interestingly, WiMAX has recently benefitted from the development of low-cost monopole antennas.

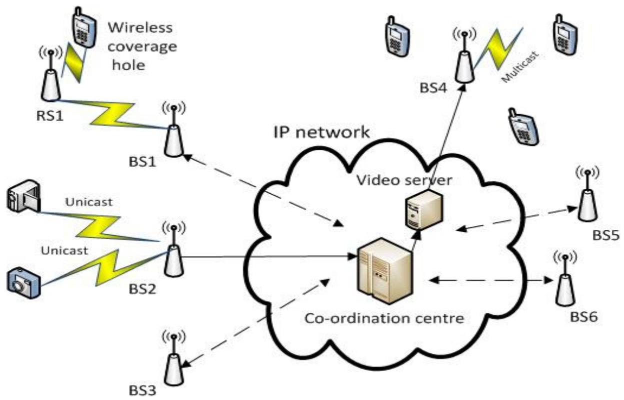

Fig. (1) Example of unicast/multicast operation:

Joint unicast/multicast streaming

Unfortunately, if the same video streaming system is used for unicast and multicast alike there is a risk of message implosion from repeat retransmission requests (after wireless channel errors) which implies that multicast must be treated differently from unicast. This in turn results in increased software development and subsequent maintenance costs, which indeed is the implication of prior research by others. To support this surveillance architecture, our poster proposes a versatile video-streaming scheme that can provide high-quality unicast with the aid of repair packets but still support multicast without repair packets.

Data-partitioned source coding as well as gradual decoding refresh is adopted for the mobile surveillance application. Raptor channel coding reduces computational complexity and in the scheme acts at the sub-packet level. By dynamically tuning Raptor coding provision according to channel condition estimation, cell bandwidth is not needlessly used. Data partitioning opens up the possibility of either employing unequal error protection for smaller high-priority packets or providing redundant high-priority packets. Though the scheme is demonstrated with compression by an H/264/AVC (aka MPEG-4 part 10) codec, it can take advantage of future provision of data-partitioning within the High-Efficiency Video Coding (HEVC) standard (aka H.265 or MPEG-H Part 2). HEVC, despite its more complex quad-tree structures is not incompatible with such an error resilience feature, which is needed for wireless, even if there is a present emphasis within the standard on delay-susceptible HTTP pseudo-streaming.

Contact:

Dr Martin Fleury,

University of Essex, U.K.

fleum@essex.ac.uk

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Elements of the solution

Data partitioning

In H.264/AVC, when data-partitioning is enabled, every slice is divided into three separate partitions stored in Network Abstraction Layer Units (NALUs). A NALU of type A comprises the most important information of the compressed video bit-stream, such as motion vectors. A NALU of type B contains the intra-coded transform coefficients on a per macroblock (MB) basis, while a type C NALU carries the transform coefficients of the motion-compensated, inter-coded MBs. In HEVC, coefficients from Transform Units (TUs) are suitable for partitioning into HEVC NALUs.

Raptor channel coding

Raptor coding is a systematic code, with a belief propagation decoding algorithm that is linear in complexity. In Fig. 2 for application-layer coding, complementing physical-layer coding, an outer block-code creates redundant nodes which are subsequently coded with a rateless code such as the Luby Transform (LT). Rateless codes allow additional repair data to be generated. However, for reasons of reducing latency, our byte-level usage differs, from prior packet-level usage by others.

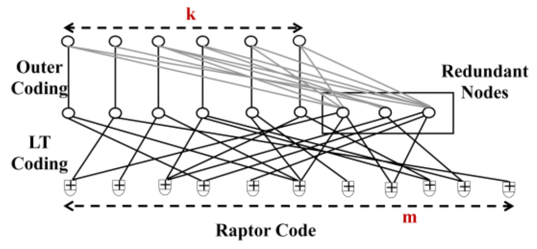

Fig. (2) Systematic, two-stage Raptor rateless coding.

IEEE 802.16e mandates MS detection of channel conditions. In these tests, the instantaneous data loss rate, *BL*, was used to calculate the amount of redundant data as:

$$R = L\times BL+(L\times BL^2)+(L\times BL^3)\ldots = L/(1-BL)-L$$

as a guard against packet corruption.

Findings

For two test video clips, *Paris* and the more active *Football*, Fig. (3) shows packet drop rates if the *same* amount of redundant data are added to unicast and multicast streams. Fig. (4) shows the packet end-to-end delay for those corrupted packets requiring a single permitted retransmission of repair data piggybacked onto the next scheduled packet. Multicast latency is approximately half that of corrupted packets. Multicast does not allow retransmissions due to the threat to the server of multiple requests. Hence, its video quality (PSNR) is reduced in Fig. (5). However in Table 1, we show the redundant data overhead from sending additional redundant data to compensate for lack of retransmissions: it is less than 10% for similar video quality to unicast. Redundant partition-A packets in conjunction with error concealment at the decoder can add further robustness and guard against traffic congestion at the video server. This makes for a versatile unicast/multicast, HEVC compatible, video surveillance system.

CBR data rate:	Average data rate overhead % for multicast, adaptive Raptor code
Football at 500 kbps	***8.05***
Football at 1 Mbps	***8.79***
Paris at 500 kbps	***7.53***
Paris at 1 Mbps	***7.78***

Table (1) Mean overhead from adaptive channel coding for multicast CBR streaming.

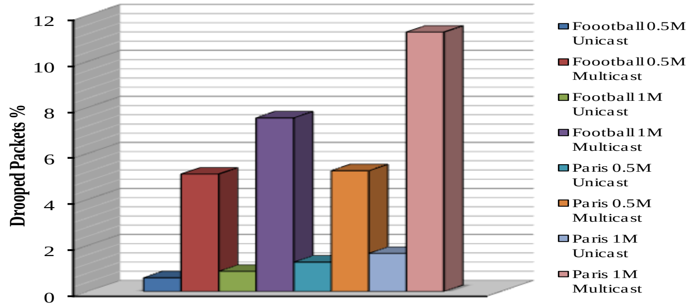

Fig.(3) Packet drop rates for unicast and multicast with adaptive Raptor coding. 0.5M= 0.5Mbps, 1M = 1 Mbps.

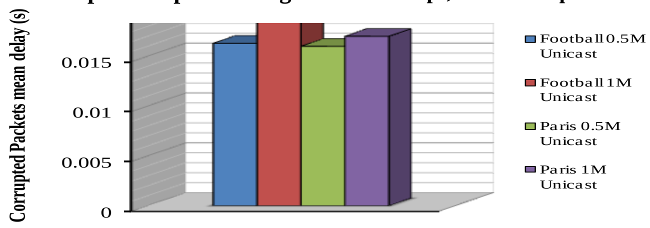

Fig.(4) Corrupted packets' mean delay for unicast.

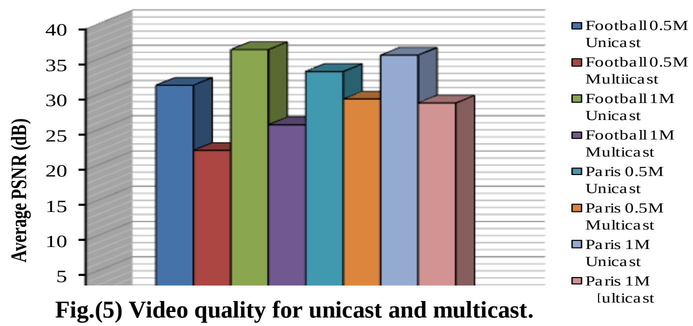

Fig.(5) Video quality for unicast and multicast.