

# **Enhancing the Quality of Video Streaming over Unreliable Wireless Networks**

A Thesis Submitted for the Degree of  
Doctor of Philosophy

By

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in

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# Abbreviations

<b>Abbreviations</b>	<b>Descriptions</b>
<b>HEVC</b>	High Efficiency Video Coding
<b>QoS</b>	Quality of Service
<b>EC</b>	Error Concealment
<b>HD</b>	High Definition
<b>UHD</b>	Ultra High Definition
<b>ME</b>	Motion estimation
<b>WMSN</b>	Wireless Multimedia Sensor Network
<b>PLR</b>	Packet Loss Ratio
<b>QoE</b>	Quality of Experience
<b>VSP</b>	Video Service Provider
<b>ITU-T</b>	International Telecommunication Union-Telecommunication
<b>VCEG</b>	Video Coding Experts Group
<b>MPEG</b>	Moving Picture Experts Group
<b>VCL</b>	Video Coding Layer
<b>NAL</b>	Network Abstraction Layer
<b>MIMO</b>	Multiple-Input-Multiple-Output
<b>ER</b>	Error Resilience
<b>VoD</b>	Video on Demand
<b>FEC</b>	Forward Error Correction

<b>ARQ</b>	Automatic Repeat Request
<b>QP</b>	Quantisation Parameter
<b>SHVC</b>	Scalable High Efficiency Video Coding
<b>MANETs</b>	Mobile Ad-hoc Networks
<b>BL</b>	Base Layer
<b>EL</b>	Enhancement Layer
<b>JCT-VC</b>	Joint Collaborative Team on Video Coding
<b>CTU</b>	Coding Tree Unit
<b>MB</b>	MacroBlock
<b>CTB</b>	Coding Tree Block
<b>CB</b>	Coding Block
<b>CU</b>	Coding Unit
<b>SCB</b>	Smallest Coding Block
<b>LCB</b>	Largest Coding Block
<b>PB</b>	Prediction Block
<b>PU</b>	Prediction Unit
<b>MV</b>	Motion Vector
<b>TB</b>	Transform Block
<b>DCT</b>	Discrete Cosine Transform
<b>DST</b>	Discrete Sine Transform
<b>FS</b>	Full Search
<b>TSS</b>	Three Step Search
<b>FSS</b>	Four Step Search

<b>DS</b>	Diamond Search
<b>HS</b>	Hexagonal Search
<b>MC</b>	Motion Compensation
<b>URQ</b>	Uniform Reconstruction Quantisation
<b>SAO</b>	Sample Adaptive Offset
<b>CABAC</b>	Context Adaptive Binary Arithmetic
<b>HM</b>	HEVC test Model
<b>AI</b>	All-Intra
<b>LDP</b>	Low-Delay P
<b>LDB</b>	Low-Delay B
<b>RA</b>	Random Access
<b>GoP</b>	Group of Pictures
<b>RDO</b>	Rate Distortion Optimisation
<b>RD</b>	Rate Distortion
<b>SAD</b>	Sum of Absolute Difference
<b>TSAD</b>	Hadamard Transformed SAD
<b>SSE</b>	Sum of Square Error
<b>SVC</b>	Scalable Video Coding
<b>PSNR</b>	Peak-Signal-to-Noise-Ratio
<b>fps</b>	frames per second
<b>FIR</b>	Finite Impulse Response
<b>SHM</b>	SHVC test model
<b>LUT3D</b>	3D Look-Up-Table

<b>SEC</b>	Spatial Error Concealment
<b>TEC</b>	Temporal Error Concealment
<b>HEC</b>	Hybrid Error Concealment
<b>PDF</b>	Probability Density Function
<b>KDE</b>	Kernel Density Estimation
<b>MESE</b>	Mean Error Square Estimator
<b>DP</b>	Dynamic Programming
<b>MFI</b>	Motion Field Interpolation
<b>FBM</b>	Flexible Block Matching
<b>TLRA</b>	Tensor Low Rank Approximation
<b>MVE</b>	Motion Vector Extrapolation
<b>MDC</b>	Multiple Description Coding
<b>EII</b>	Exemplar-based Image Inpainting
<b>SI</b>	Spatial Interpolation
<b>PDIP</b>	Primal-Dual Interior Point
<b>SO</b>	Spare Optimisation
<b>RoI</b>	Region of Interest
<b>PIR</b>	Passive Infra Red
<b>BS</b>	Base Station
<b>WSN</b>	Wireless Sensor Network
<b>UWB</b>	Ultra Wide Band
<b>MSE</b>	Mean Square Error
<b>CSP</b>	Cloud Service Provider

<b>SaaS</b>	Software as a Service
<b>PaaS</b>	Platform as a Service
<b>IaaS</b>	Infrastructure as a Service
<b>CD</b>	compact Disc
<b>DVD</b>	Digital Video Disc
<b>BMA</b>	Block Matching Algorithm
<b>FC</b>	Frame Copy
<b>FI</b>	Frame Interpolation
<b>IV</b>	Input Video
<b>OV</b>	Output Video
<b>IB</b>	Input Block
<b>RB</b>	Reference Block
<b>SW</b>	Search Window
<b>TDLS</b>	Two Dimensional Logarithmic Search
<b>SES</b>	Simple and Efficient Search
<b>ARPS</b>	Adaptive Rood Pattern Search
<b>SSD</b>	Sum of Square Difference
<b>SHD</b>	Sum of Hamming Distance
<b>MAD</b>	Minimum Absolute Difference
<b>LSAD</b>	Locally scaled SAD
<b>LSSD</b>	Locally scaled SSD
<b>ZSAD</b>	Zero-mean SAD
<b>ZSSD</b>	Zero-mean SAD

<b>NCC</b>	Normalised Cross Correlation
<b>ZNCC</b>	Zero-mean NCC
<b>IFC</b>	Intelligent Frame Creation
<b>CF</b>	Concealed Frame
<b>AFO</b>	Adaptive Filter Output
<b>AMF</b>	Adaptive Mean Filter
<b>RAM</b>	Random Access Memory
<b>SNR</b>	Signal-to-Noise-Ratio
<b>SFI</b>	Scalable Frame Interpolation
<b>TZS</b>	Test Zone Search
<b>RS</b>	Raster Search
<b>FME</b>	Forward Motion Estimation
<b>FMV</b>	Forward Motion Vector
<b>BME</b>	Backward Motion Estimation
<b>BMV</b>	Backward Motion Vector
<b>MSN</b>	Multimedia Sensor Node
<b>IPS</b>	Indirect Path from Sender
<b>ACK</b>	Acknowledgement
<b>NACK</b>	Negative ACK
<b>IoT</b>	Internet of Things
<b>SDN</b>	Software Defined Network

# Abstract

Real-time video transmission over unreliable wireless networks remains a serious challenge due to bandwidth limitation and sensitive nature of video bitstreams generated by today's complex video encoders, e.g., High Efficiency Video Coding (HEVC/H.265). These compressed video bitstreams face packet-drop problem when transmitted over unreliable wireless networks. The effect of packet-drop on the received video quality can be minimised in two ways 1) increasing Quality of Service (QoS) by adopting efficient routing schemes between source and destination, and 2) maintaining video quality at receiver's side by applying smart and real-time-based Error Concealment (EC) techniques. The QoS refers to the capability of a transmission network to provide better service to selected network traffic. It is a generic term and can be applied to any data transmission network. The term video quality refers to perceived video degradation and is compared to the original video. In this dissertation, we explore the above mentioned two ways and propose a comprehensive solution for real-time video transmission over unreliable networks with the contributions as follows.

1. An efficient, lightweight and real-time EC algorithm is proposed to conceal the missing/lost video frames in H.265 encoded HD videos. The EC algorithm is based on threshold-based distributed Motion Estimation (ME) scheme and utilises only two video frames to estimate the missing one, thus eliminating the need for a large buffer and processing of a bundle of video frames to estimate the missing one.
2. Scalable video coding produces multiple interrelated bitstreams of a single video with different bitrates. For scalable bitstreams, we propose a lightweight and real-time EC algorithm to cover up the effects of missing/lost video frames. Due to complicated nature of scalable video bitstreams, our proposed EC algorithm utilises three previously processed video frames along with their master video frames to perform threshold-based distributed ME to estimate the missing video frames in

enhancement layer.

3. We propose a feed-back-based on-demand multipath routing scheme over a multi-hop Wireless Multimedia Sensor Network (WMSN) to ensure the QoS. The feed-back helps in deciding the optimum path between sources and destinations and reduces the Packets Loss Ratio (PLR) during the transmissions. On-demand connection assists in saving the available network resources while multipath routing aids in maintaining the connection between sources and destinations.

The proposed research makes notable contributions to designing a QoS-supported HD video streaming paradigm to deliver HD videos over unreliable networks and to maintain the received video quality on resource-constrained mobile terminals.



# List of Publications

## Journal Papers

1. Muhammad Usman, Xiangjian He, Kin-Man Lam, Min Xu, Syed Mohsin Matloob Bokhari, and Jinjun Chen, Frame Interpolation for Cloud-Based Mobile Video Streaming, *IEEE Transactions on Multimedia*, vol. 18, No. 05, pp.831-839, 2016.
2. Muhammad Usman, Xiangjian He, Kin-Man Lam, Min Xu, Syed Mohsin Matloob Bokhari, and Jinjun Chen, Cloud-Hosted and Assisted Scalable Video Coding and Concealment for High Definition Videos, *IEEE Transactions on Cloud Computing*, (Accepted for Publication on 22 July 2017).
3. Muhammad Usman, Mian Ahmad Jan, Xiangjian He, Min Xu, and Kin-Man Lam, A Joint Framework for QoS and QoE for Video Transmission over Wireless Multimedia Sensor Networks, *IEEE Transactions on Mobile Computing*, (Accepted for Publication on 03 August 2017).

## Conference Papers

1. Muhammad Usman, Xiangjian He, Min Xu, and Kin-Man Lam, Survey of Error Concealment Techniques, *Research Directions and Open Issues, 21st International Packet Video Workshop in Conjunction with 31st Picture Coding Symposium PCS*, pp.233-238, 2015, IEEE).
2. Muhammad Usman, Mian Ahmad Jan, Xiangjian He, and Priyadarsi Nanda, Data Sharing in Secure Multimedia Wireless Sensor Networks, *15th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom)*, 2016, IEEE.