# On the Perceived Quality Evaluation of Opportunistic Mobile P2P Scalable Video Streaming

Constandinos X. Mavromoustakis
Computer Science Department
University of Nicosia
Nicosia, Cyprus
mavromoustakis.c@unic.ac.cy

Ilias Politis
School of Science and Technology
Hellenic Open University
Patras, Greece
ilpolitis@gmail.com

George Mastorakis, Evangelos Pallis
Department of Informatics Engineering
Technological Educational Institute of Crete
Heraklion, Crete, Greece
gmastorakis@staff.teicrete.gr; pallis@pasiphae.eu

Ciprian Dobre
Faculty of Autonomic Control and Computers
University Politehnica of Bucharest
Bucharest, Romania
ciprian.dobre@cs.pub.ro

Charalambos Mysirlidis, Tasos Dagiuklas
School of Science and Technology
Hellenic Open University
Patras, Greece
babis.ms@gmail.com; dagiuklas@eap.gr

Katerina Papanikolaou
Department of Computer Science and Engineering
European University Cyprus
Nicosia, Cyprus
k.papanikolaou@euc.ac.cy

***Abstract*—This paper studies the evaluation of the video streaming over Mobile Peer-to-Peer (MP2P) networks using Scalable Video Coding. The proposed research framework exploits the MP2P diversity characteristics where each node acts as a Mobile Peer for every neighboring node in a relay-based communicating path. Mobile Peers use a common look-up table to request video streaming resources in order to estimate the video packets transfer duration in the end-to-end path. The collaborative streaming is achieved through the data packets replication policy, which uses a bounded upper time limitation for the video packets of each layer (Use of Scalable Video). Each node/device utilizes a specified amount of capacity for both channel and storage purposes. Different scenarios have been introduced in this paper towards evaluating the video streaming policy in the MP2P system, using a real-time probabilistic Fractional Brownian Motion (FBM) and a Random Waypoint (RWP) Mobility model. In both models, nodes move according to certain probabilities, location and time. Intermittent connectivity occurs while nodes claim video streams, whereas promiscuous caching policy enables -where possible- recoverability of lost packets offering priority to packets from the base layer. The simulation results show that FBM provides better objective and subjective quality results for two video sequences resolution, in the MP2P *network configuration.***

***Keywords*— *Mobile Peer-to-Peer Video Streaming; Scalable Video Streaming; quality evaluation of video streaming***

## I. Introduction

Wireless networks are prone to sudden failures as the limited connectivity prevents continuity in any resource sharing process. As an effect the establishment and maintenance of the connectivity, while transmitting in an end-to-end relay path, comprises an important design factor for an end-to-end video communication.

Peer-to-peer video streaming allows the delivery of the video content by exploiting user resources [1]. Peer-to-peer video streaming over Mobile ad-hoc environment poses additional challenges, due to the resource constraints that crucially affect the quality of service [2], [3]. When considering video streaming in such environments, there are many resource issues that need to be faced like the end-to-end reliability problems, where in most cases the relay path is consecutively changed resulting in additional delay in the streaming process [4]. In turn, the availability of any requested resources are aggravated by the dynamically changing nature of such networks and as a result there is severe throughput degradation in Quality of Service (QoS) and Quality of Experience (QoE).

The present work is motivated by the above restrictions that exist in Mobile Peer-to-Peer (MP2P) systems, seeking for nodes in order to assign to them -as mediator nodes- potential buffered video data packets of the video streams in an end-to-end path. Nodes use the cooperative caching in order to significantly reduce the losses of video packets, which will result in aggravation of the end-to-end performance. The present work uses the n-hop replication mobility, which is based on the cache replication strategy [5] where the mobile nodes in the relay path cache requested high ranked resources onto other neighboring nodes in order to be available during a streaming request. The scheme takes into consideration the density of the nodes in the relay region and the mobility pattern of each node in the path in order to adequately stream -within a specified duration- any requested packets. The aim of this paper is to assess the impact of this scheme on video quality using both objective and subjective metrics.

The structure of this work is as follows: Section 2 describes the opportunistic mobile P2P streaming, followed by Section 3 which presents the simulation environment. Section 4 presents the performance evaluation of the proposed scenario, followed by Section 5 with the video quality evaluations and foundations. Section 6 presents the conclusions as well as potential future directions.

## II. OPPORTUNISTIC P2P STREAMING

In opportunistic mobile P2P streaming, each node acts as a Mobile Peer for each neighbor by using a common look-up table and estimates the end-to-end path video packets duration. Existing P2P and MP2P video streaming protocols assume that the videos are long and independently served from each other [6]. Due to node/device mobility and/or failure, the network topology may vary with time. Therefore, the evaluation of the appropriate value of fundamental device parameters (e.g., the optimal caching parameter [7] in accordance with other tuned measures) is a difficult task. In our evaluated framework, the mobile Peers request video packets in a collaborative manner, whereas Peers use the promiscuous caching policy [8] in order to effectively buffer the lost video packets to nearby Peers and forward them thereafter to the destination node. Video packet segmentation policy is used in order to enable each packet to be relayed via different MP2P paths to the destination node *(i)*. A standalone MP2P architecture is used where each node acts independently in manipulating the requested resources allowing cooperation among nearby peers. When streams of packets are requested by the recipient node, each node in the end-to-end path should be available in order to correctly receive the stream. In any other case, the Dynamic Caching ([8][9]) is activated to buffer the packets for a specified amount of time on a nearby 1-hop node. The key elements in the MP2P mechanisms are shown in contrast to the resource manipulation mechanisms in Fig. 1. While a video is requested by a node, each packet assigns a deadline in order to be rejected in case that it will not reach its destination within the time limitations. The topology is controlled through the Definition 1.1 (Dense Nodal Relay Region). In case that the destination is not available or 'on-line' (connected), the Dynamic Caching mechanism takes place which allows passive buffering of replicas of the packets on 1-hop neighboring nodes to destination. As Fig. 2 shows, the Dynamic Caching ([8][9]) mechanism is applied and enables the packets to be "cached" in the 1-hop neighboring nodes of the Peer that acts as a forwarding node or is the destination node. In case that the cache process is no longer available to host the additional packet chunks, packets from the enhancement layer are discarded first. In turn the delay epoch $E_{i(t)}$ of each node is defined as a function of the number of created replicas as shown in the next paragraph.

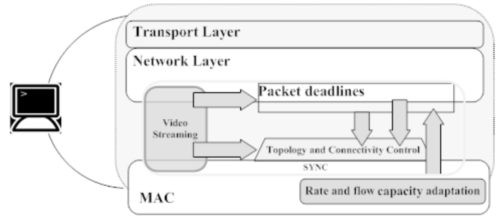


Fig. 1: Key elements in the MP2P mechanisms are shown in contrast to the resource manipulation mechanisms

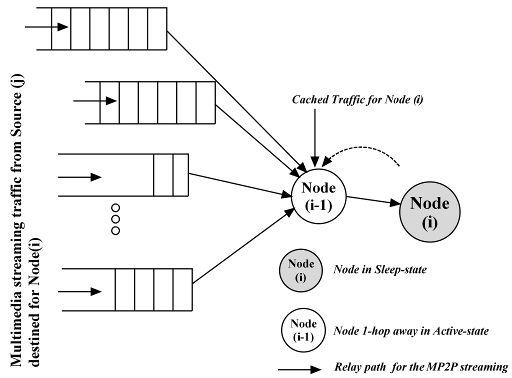


Fig. 2: A schematic diagram of the caching mechanism addressed in this work

The collaborative streaming uses a bounded upper time limitation for each stream transfer requirements. In addition, in order to allow an uninterrupted communication between the source and the destination the following definition should be satisfied.

*Definition 1.1 (Dense Nodal Relay Region):* The dense population region of a certain transmitter–relay node pair *(u,w)* traversing *n* paths is defined as the relay region, which has any end-to-end connectivity in the relay path at a given time as follows:

$$\Delta R_{u\to w} = \{(x,y,u) \in \Re^2 : W_{u\to w\to(x,y,u)} > P_{u\to(x,y,u)} \forall u \in P_n\}. \quad (1)$$

where $P_{u\to w\to(x,y)}$ is the probability for a certain node *u* to transfer the file chunks from a source node *x* to destination node *y* via the *w* based on the connectivity and the delay of the response of the nodes. Thus, in an end-to-end path $\forall u \in P_n$ the minimized ping delays between the nodes in the end-to-end path, is evaluated according to the:

$$d_p = Min \sum_{i=1}^{j} D_i \quad (2)$$

where $D_i$ is the delay from a node *i* to node *j*, and $d_p$ is the end-to-end available path. Therefore the delay epoch $E_{i(t)}$ of each node is defined as a function of the number of created replicas on the j-hosts as follows:

$$E_{i(t)} = d_{r_{j\to i}} \cdot r_{j\to i} / Total\_d_{r_{j\to i}} \quad (3)$$

where $D$ is the delay via the ping assigned durations, $r_{i \to j}$ is the number of replicas from node i to j in the j-hop path and $Total\_d_{r_{i \to j}}$ is the total duration that all the requested replicas can be downloaded from the j-hop path.

In order to specify a numerical upper bound of the replicas that are created for allowing availability of the requested packet chunks, a cost function is defined that measures the generic case of *n-hop replications*, as follows:

$$R_N(t) = \sum_{k=1}^{N-1} n_{i \in N} \quad (4.1)$$

where $R_N$ is the number of the request-driven replicas and $n_i$ is the number of file chunks for N nodes that demand the i-content chunks of the file. The cost function of the N-hop replication is evaluated as a function of the access rate and the update rate as follows:

$$C_{Ni} = \frac{AR_i \cdot N}{UR_i \cdot Size_{i-chunk}} \quad (4.2)$$

where $C_{Ni}$ is the cost for the N-hop replicas created, $AR_i$ is the access rate according to [3] and $UR_i$ is the update rate.

Moreover, each node utilizes a specified amount of capacity for both channel and storage purposes. The channel capacity ranges from 0.5 Mbps to 11Mbps, whereas, the storage capacity of each one of the nodes is considered asymmetrical ranging from 100MB to 0.5GB. The latter was considered in order to enable a realistic scenario where, the nodes estimate the saturation level of their storage in contrast to the buffering activity [8] of the requested file chunks. Different scenarios have been introduced in order to evaluate the video streaming policy in MP2P systems using different mobility frameworks like the real-time probabilistic Fractional Brownian Motion (FBM) mobility model and the Random Waypoint (RWP) Mobility model, as shown in the next sections.

## III. SIMULATION ENVIRONMENT

The scenario was implemented and simulated using discrete event simulation model using Java-based simulator [10]. The simulated scenario was evaluated for the achievable throughput, reliability degree and delay-bounded transmissions (streams that are requested by nodes and have delay limitations). This work exploits the characteristics of the realistic mobility models by utilizing the probabilistic Fractional Brownian Motion (FBM) and the Random Waypoint (RWP) models. In FBM, nodes move according to certain probabilities, location and time and these characteristics have a correlation in time. In RWP mobility model, the node moves with a certain speed (<6KM/h) from node to node in the graph in the following random walk/movement. Towards implementing such scenario, the spine model [7] was used, exploiting a common look-up application service for resource and multimedia streaming sharing among mobile nodes. Topology of a 'grid' based network was modeled, according to the grid approach described in [10]. For the simulation of the proposed scenario, the varying parameters described in previous section were used, exploiting a two-dimensional network, consisting of maximum 100 nodes/per measured area, provided that there is a relay path $\Delta R_{u \to w}$.

During the simulation of the proposed scenario we used the varying parameters as set in Table I by using a two-dimensional network, consisting of maximum 180 mobile nodes connected with random connectivity.

TABLE I. LIST OF SIMULATION PARAMETERS

| Parameter | Value |
|---|---|
| Channel Capacity | 0.5 Mbps to 11Mbps |
| Packet classification | "Bursty" and "don't-care" |
| Nodes Number (connected in a MP2P manner) : losses in nodal connectivity | 100 : 3%;<br>150 : 5%;<br>180 : 7% |
| Mobile Nodal capacity | 100MB-0.5 GB |
| Area coverage area for nodes (x*y) | (1 Km *1Km) |
| Maximum peers connected (static P2P manner) | 10..30 |
| Pause time | 0,150seconds |
| Nodal maximum speed | 1, 5, 15, 30 meters/second |
| Simulation Time | 20000 seconds |
| Bandwidth | 1 Mbps -11 Mbps |

Moreover, two testing video sequences YUV 4:2:0 color 4CIF (704 × 576 pixels) "crew" and "soccer" at 60 fps encoded SVC video were used during the experimentation set-up [11]. In the case of SVC encoding, SNR scalability mode is selected with 2 layers (1 base layer and 1 enhancement layers) created using QP = 36 for the base layer and QP = 30 for the enhancement layer. Without loss of generality, we assume a single NALU packetization with size 1460 bytes (one RTP packet – one NAL unit) with RTP packet size equals to 1500 bytes. The generated video packets are delivered through simulated MP2P network. Table II summarizes the SVC video encoding parameters used during the experimentation.

TABLE II. LIST OF H.264 SVC ENCODING PARAMETERS

| Parameter Name | Parameter Value |
|---|---|
| Video Codec | H.264/Scalable Video Coding |
| Video Sequence | YUV 4CIF (704 × 576 pixels) |
| Scalability Mode | Quality scalability (MGS) |
| No. of layers | 1 base, 1 enhancement |
| Number of frames | 600 |
| Encoder quantization parameters | 36 (Base), 30 (Enhancement) |
| NAL Unit Size | 1460 byte |
| RTP Packet Size | 1500 byte |

## IV. PERFORMANCE EVALUATION

### A. Network Performance Evaluation

Fig. 3 illustrates the average packet loss for both layers under three different loss connectivity scenarios.

It is evident that the FBM gives lower packet loss rates from both layers for the two video sequences. This is due to the nature of the FBM, which associates the previous likelihood of the nodal movements with the next with a difference less than 50% as real-time users do. RWP mobility has random nature in extracting the likelihood of the movements and the direction of nodes and therefore this aggravated the average packet loss rate for both layers.

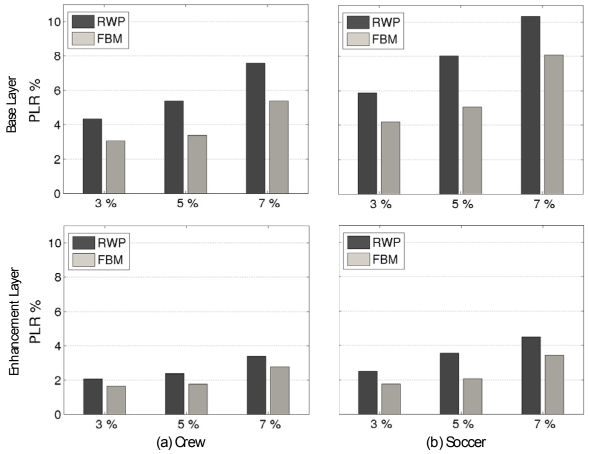


Fig. 3: Average Base and Enhancement Packet Loss rate for three loss connectivity scenarios

## *B. Video Objective Evaluation*

Fig. 4 illustrates the average PSNR for the videos "Crew" and "Soccer" respectively, under the MP2P for the two mobility schemes (FBM and RWP). It is evident that the FBM gives better values in terms of average PSNR for both video sequences for different loss connectivity scenarios.

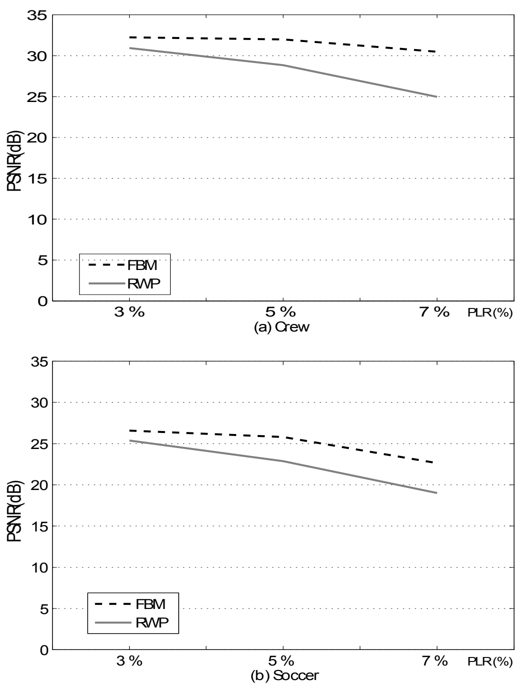


Fig. 4: Average PSNR for three loss connectivity scenarios

## *C. Subjective Evaluation*

The subjective evaluation has been carried out using the recommendations by ITU-T BT.500 for laboratory environments [12]. The following parameters have been considered: daylight conditions, mid gray background using appropriate curtains. Two High quality side-by-side LCD displays have been used for the subjective evaluation, where the first display illustrates the original and the second the distorted video sequence. The high-quality raw video used, has been recorded with professional equipment using YUV 4:2:0 format.

All subjects that participated at the evaluation are graduate students and faculty members of the Hellenic Open University, School of Science and Technology, Greece. For the evaluations of the videos, 30 subjects have been used. During the test setup phase, each subject gets familiar with scoring procedure and video artifacts.

In this methodology, the Simultaneous Double Stimulus for Continuous Quality Evaluation method (SDSCQE) has been used [12]. The votes are sampled every 0.5, as described in the SDSCQE in ITU BT-500 standard. In this voting procedure, the next step regards the removal of vote outliers. These votes refer to the cases where the difference between mean subject vote and the mean vote for this test case from all other subjects exceeds 15%. This is a general rule that has been also used in other research works [13], [14], [15].

Fig. 5 illustrates the average MOS for both mobility models for both video sequences. It is shown for both sequences that FBM gives better results in terms of average MOS.

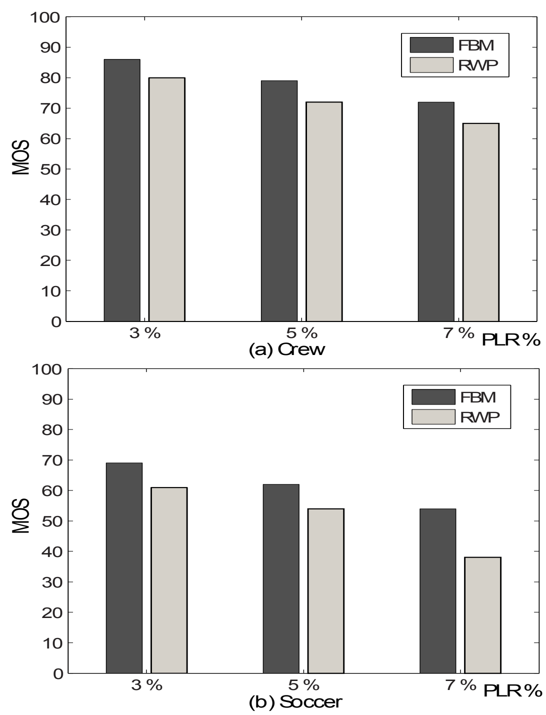


Fig. 5: Average MOS for three loss connectivity scenarios

## V. CONCLUSIONS

This work performs quality evaluation of an opportunistic MP2P streaming process using Scalable Video Coding. Every node, by using a common look-up table, requests specific video streams from other peer(s) in a collaborative manner and exploits the promiscuous caching policy for buffering file chunks that were discarded during nodal losses. For the evaluation of the proposed scenario, different mobility models were used, whereas intermittent connectivity occurs due to the nodal movements. The conducted simulation experimental evaluation shows that the MP2P communication with the FBM exposed by nodes, provides a better objective and subjective evaluation outcomes for two video sequences resolution.

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