A Comprehensive Evaluation of Different Loss Recovery Schemes in Peer-to-Peer Live Video Streaming over WMNs

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***Abstract*—In the recent years, Wireless Mesh Networks (WMNs) has become popular for video multicasting. Although peer-to-peer communication lets wireless nodes improves the functionality of the video streaming applications over WMNs, required level of Quality-of-Service (QoS) is one of the most important challenges in these systems. Therefore, it is necessary to introduce new or enhance existing techniques in order to increase QoS for providing better perceived video quality on receivers. In this paper, different loss recovery schemes in peer-to-peer live video streaming over wireless mesh networks are evaluated precisely. The obtained results show how the provided efficiency by each of these schemes can improve the level of the introduced QoS in peer-to-peer live video streaming over WMNs.**

***Keywords:* WMNs, Peer-to-Peer, Live Video Streaming, Loss Recovery**

I. INTRODUCTION

Nowadays, wireless networks, especially the IEEE 802.11 standard [1], have been very popular among end-users, because of the provided mobility and flexibility features by them. However, scalability, high cost of implementation and existence of wired backbone are the most important challenges in this standard. Wireless mesh networks, which can be established based on the existing wireless standards, tries to cope with these issues as much as possible. Therefore, the IEEE group introduced the IEEE 802.11s [2] as an efficient and popular standard for WMNs to address mentioned challenges. Recent studies have shown that WMNs works well in many traditional data services as well as in content-rich multimedia applications. The current wireless infrastructure has many open issues in multimedia streaming systems such as IPTV [3], Video on Demand, video conferencing, and video surveillance. Some of these open issues are dynamic available bandwidth in peers, shadowing and channel loss rate. Recent advances in path selection protocols and message re-routing increase the efficiencies of these networks while considerably reduce the burst loss effects. In this sense, multi-hop communication between two nodes may be performed over different paths and this is one of the main characteristics of this type of networks. However, because of wireless nature of WMNs and multi-hop communication among nodes, packet loss is an important remained issue in them. As can be seen in Figure 1, a node communicates with the server across multi-hop path consists of wireless nodes and Access Points (APs).

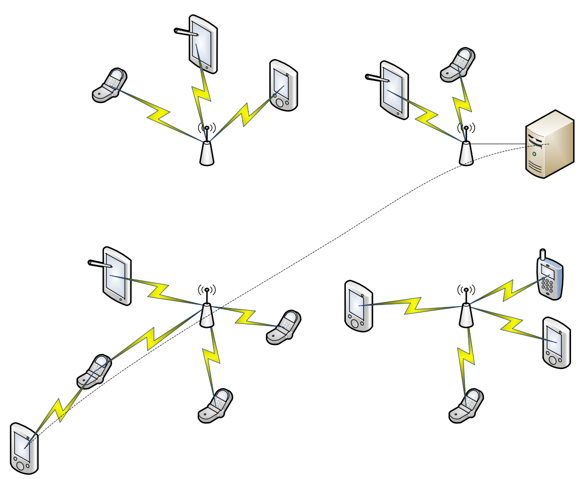

Fig. 1. Wireless Mesh Network Structure

Advances in computer networking and recent media streaming technologies are combined with recent advances in home computers and makes multimedia streaming as a new attractive technology in the Internet. High quality video streaming requires large enough bandwidth and low error prone links. Hence, communication and storage costs of this application are still significant. Unicast protocols send content directly from server to each recipient and are not scalable in large networks like the Internet. Multicast protocols send a separate copy of data content from the server to many recipients with high infrastructure cost, especially in video streaming applications. CDN (Content Delivery Networks) servers emerged as a recent prevalent technology, but this technology imposes high cost of infrastructure and maintenance to the system [4].

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Peer-to-Peer computer networking [5, 6] is the one of most important deployed networks so that each computer can act as a client or as a server for the other computers in the network without the need of central server [7]. In contrast to the traditional client–server model where only the server supplies and clients consume, in P2P networks, each peer participate in content sharing and send or receive the content efficiently. Scalability and low cost infrastructure as well as recent advances in content sharing protocols increase the willingness of participating in these networks. Thanks to the P2P networking, more efficient video streaming systems over the Internet can be proposed [8]. Moreover, many live streaming applications such as IPTV can be adopted with low infrastructure cost. However, because of peer churning and heterogeneous available resources in peers [9], the probability of packet loss event is noticeable in P2P streaming [5, 10]. This event has enormous side effects on efficient peer-to-peer video streaming.

In the H.261 video compression standard [11], a picture is on the top of the coding hierarchy and other successive frames are similarly encoded. In order to assist random access to picture sequence the structure of determinate hierarchy group of pictures, called GOP, is implemented [12]. In a GOP structure, the hierarchy contains three different frames called I, B and P where I frame is on the top of hierarchy as a reference frame in that GOP. In other words, all other frames can be decoded and corrected based on this frame. I-frames is followed by an arrangement of P- and B-frames where P-frames contain difference information from the preceding I- or P-frames. The B-frame is dependent on the previous and the next I- or P-frames within a GOP. The GOP structure is often referred by two important numbers i.e. N_P which indicate the number of P-frames in a GOP structure and N_{BP} which indicate number of B-frames between two I- or P-frames.

Because of the existing dependencies among video frames, any error in this sequence can be propagated to the whole GOP [13]. Error resilience video streaming can improve the perceived video quality on receivers. In this sense, Multiple Description Coding (MDC) and other error resilience methods have low effects on P2P video streaming. Error recovery methods like Forward Error Correction (FEC) and retransmission can improve the introduced amount of QoS in P2P video streaming in error prone networks such as WMNs. However, the main question is that is it necessary to apply these method on the whole video sequences in P2P video streaming over error prone networks such as WMNs?

In this study, the effects of different parameters and packet loss recovery schemes in peer-to-peer video streaming over WMNs are evaluated using OMNeT++ [14] simulator.

II. Related works

Retransmission and forward error correction are the two most used techniques in packet loss recovery. Several loss recovery schemes for peer-to-peer video streaming are proposed [7, 15, 16, 17]. We can divide these schemes into three main categories including Retransmission-based, forward error correction-based and hybrid-based approaches. Retransmission technique is the most well-known and applied approach in video streaming [16] over WMNs. However, it suffers from many issues, because of the error prone native channels in WMNs including channel fading, interferences and NAK implosions, especially where distance between two neighbor peers is long [18]. Although using many NAK messages increases the recover probability of packet, it considerably consumes the available bandwidth [17]. Moreover, the channel will be busy as much as possible.

Forward error correction methods only protect packets by packet redundancy like Reed-Solomon correction codes and recover some packet losses that the enough redundancy of lost packets received to the end peer, but in the situation of burst packet losses where is very conventional in wireless links, forward error correction isn't a suitable method. Many researches has devoted in hybrid methods where combined the forward error correction and the retransmission methods [7, 19]. In hybrid methods, a (N, K) block code was supposed where N is the size of FEC block and the N-K original packet will be generated additive to k FEC parity packets. If the end peer receives N-K packets out of N packets, it can recover the whole frame and the frame will be sent to the upper layer of that node. In case of loss event, where the end peer receive smaller number of packets than N-K packets, the peer will transmit a NAK to the sender with the information about the lost packets after a predefined time, named waiting time. The sender peer produces the parity packets again and sends it to the end peer. The authors of [7] analyzed different streaming parameters and loss recovery policies in an analytical point of view.

III. Discussion

In peer-to-peer video streaming, each peer participates in the overlay multicast as a seed while receiving video from other peers. Contrary to central video streaming approach, video frame diversity can be increased using P2P systems, especially when the size of the overlay grows while the startup time of the video streaming increases in end peer in the overlay path. In P2P video streaming, each video chunk, which consists of video frames, is encapsulated and transmitted as one or more encapsulated packet(s). In pull-based video streaming, each peer signals frame availability messages to its neighbors and they will update the frame availability statuses of their neighbors. Then each peer requests the required frame from its neighbors according to some optimization parameters like the end-to-end delay or round-trip time of the neighbor peers.

In each encapsulated video packet transmission different loss recovery approach can be adopted. Each encapsulated packet may contain some contents I, P or B frames of the video stream [12]. Figure 2 shows the dependency graph of Jurassic sample video GOP structure. According to this graph, protecting I frame is more important than other frames.

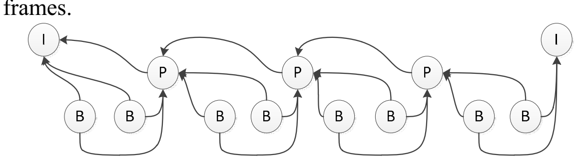

Fig. 2. Dependency graph of a sample video using MPEG4 standard

Peer-to-peer overlay over wireless mesh networks is one of the most used video streaming approaches. Using scalable WMNs, P2P video streaming overlays can be used in large scale areas.

However, due to some existing challenges in WMNs such as shared channel, interferences and shadowing [18], efficient packet loss recovery is one of most important topic among researchers in this research area. In such networks, Packet Error Rate (PER) is high and must be considered in all multimedia applications. In these networks, each wireless mesh node has a retry limit of sending NAK in the physical layer. Hence, the retransmission approach is very conventional in these networks. In the application layer and in the loss situations, the system will try up to N_{max} retransmissions so that receive the parity packets or original packet regarding to architecture of loss recovery method. In FEC method, based on the PER of channel, packet redundancy will increase. According to the equation 1, we need a redundancy at least as RFEC to maintain a residual loss probability not more than p_{max}.

$$R_{FEC} = \min\{R \mid \varepsilon \le p_{\max}\}$$
$$\varepsilon = \sum_{k=R+1}^{D+R} \binom{D+R}{k} p^k (1-p)^{R+D-k} \frac{k}{D+R} \qquad (1)$$

Where D is the number of data packets, R is the number of redundant packets and p is PER.

The peer-to-peer video streaming over WMNs is one of challengeable issues in new researches. In these networks, wireless nodes communicate with each other using path selection algorithms. MANET routing protocols can classified as [20]:

1. Proactive protocols: keep routing table of network and hence take high bandwidth for updating the routing tables.
2. Reactive protocols: establish on-demand route to the destination and hence take longer time.
3. Hybrid protocols: Routes between neighbor nodes established by proactive routing and between peripheral nodes discovered by reactive routing protocols.

In this research, ad hoc on-demand distance vector (AODV) is used for path selection in WMN.

The video distortion is high in peer-to-peer video streaming over wireless mesh networks because of many issues like mobility in these networks, high churning in mobile nodes and interference between wireless nodes. Video distortion can be evaluated as expression 2.

$$D = \frac{total\_size\_of\_lost\_frames}{total\_frame\_size} \times 100 \qquad (2)$$

IV. Performance Evaluation

The OverSim and the INETMANET packages in OMNeT++ are used for simulating the considered P2P video streaming system in this study. OverSim is an overlay and peer-to-peer network framework in OMNeT++ simulation environment which contain several models for P2P systems and overlay protocols. The INETMANET is a continuously developing framework with the emphasis on modeling wireless networking. Figure 3 shows the considered simulation modules of peer-to-peer video streaming over WMN. As depicted in this figure, the Network Layer module connected to WLAN module which simulates a WMN node Network Interface Card. Also the Network Layer module connected to the UDP module which encapsulates video frames in UDP packets.

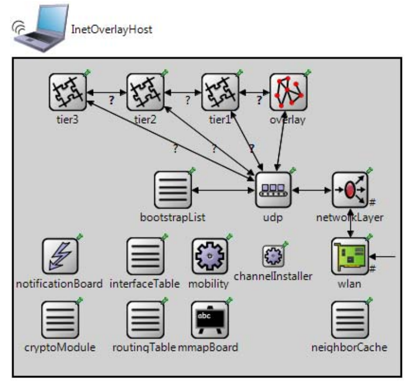

Fig. 3. OMNeT++ modules for simulating peer-to-peer video streaming over wireless mesh networks

In this research, after connecting the INETMANET framework to the OverSim package and designing the P2P video streaming system over the wireless mesh network, the distortion of video streaming evaluated. Figure 4 shows the architecture of the simulation package that simulates the peer-to-peer video streaming over WMN. Here, each peer communicate to others by the channel controller module which simulates a real channel among peers.

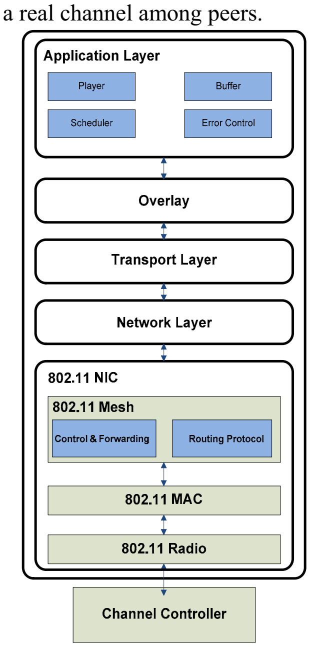

Fig. 4. Wireless Mesh Network peer module

Figure 5 shows the obtained result of this simulation for a time period of 100 seconds. The simulator ran for 10 times for the Jurassic sample video from [21]. As depicted in this figure, the distortion of video streaming over wireless mesh networks is high and a packet loss recovery method must be considered in peer-to-peer video streaming.

Different policies of FEC protection can be adopted in P2P video streaming over WMNs. In this research, different protection methods based on frame type policies are analyzed.

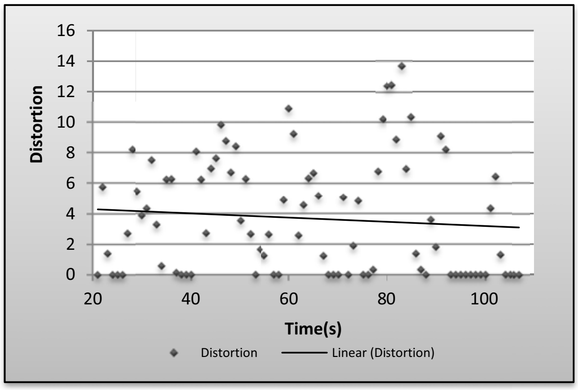

Fig. 5. Distortion of peer to peer video streaming over wireless mesh network

Table 1 shows other considered simulation conditions in this study.

TABLE I. SIMULATION CONDITIONS

Variable	Value
Simulation time	250s
Video Trace File	Jurassic
Frame per second	25
Standard codec	MPEG4
Distribution model	Random
Entrance time interval	Uniform(1,3)
Packet size	100 Kb
Propagation model	Path Loss Reception Model
N_P	3
N_{PB}	2
Peer Video Buffer	100s
Average Chunk Length	130 Kb
MTU	7891
P_{MAX}	0.001
Neighbors	Random (4,6)
MANET routing	AODV
Node mobility	Random Walk
Node mobility speed	0.001 mps

In this way, four different policies have adopted:

1- All frames protected by retransmission method and no FEC parity packet is transmitted.
2- All frames protected by retransmission method and I frames also is protected by FEC method.
3- All frames protected by retransmission method and I and P frames also are protected by FEC method.
4- All frames protected by both retransmission and FEC methods.

The result has been evaluated based on 4 performance metrics. End-to-End delay is one of the most important metrics in live video streaming. End-to-End delay in video streaming is the delay of receiving the video frame from the sending peer to the end peer across the overlay path. The result of this paper is the average of 10 time simulation runs with the random seeds. Figure 6 shows the result of the simulation. As can be seen in the results, if frames protected by the retransmission and also I frames protected by FEC parity codes, the best result will be obtained. However, there is no considerable difference between the introduced end-to-end delay due to protection of just frame I by hybrid protocol and the policy where protects all frames by hybrid protocol.

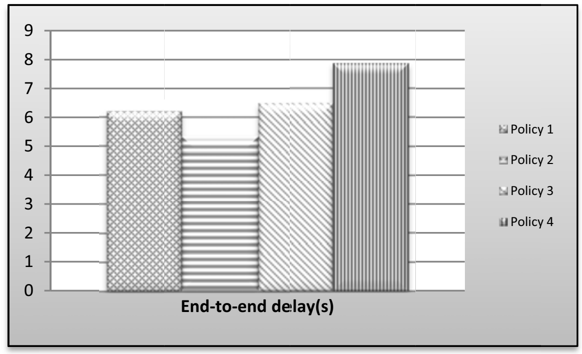

Fig. 6. End to end delay of peer to peer video streaming over wireless mesh network

As mentioned before, distortion of video in P2P video streaming over wireless mesh networks is very high. This is due to many reasons such as mobility of wireless nodes, interferences and variable bandwidth of peers that participate in the overlay. We define total distortion as the average of distortion in the whole video streaming system. Figure 7 shows the total distortion of different policies of protection in the considered P2P video streaming in our simulation.

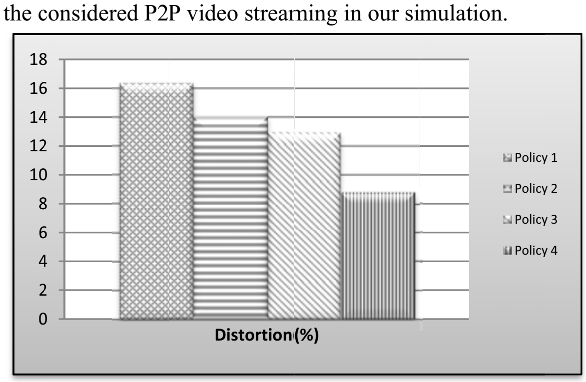

Fig. 7. Total distortion of peer to peer video streaming over wireless mesh network

Actually, the distortion in video streaming can be reduced by different loss recovery methods. The highest distortion reduction is in policy 4, where frames are protected by Hybrid protocol where all frames protected by FEC parity codes and retransmission method. But the difference among these four policies show that I frame protection using hybrid protocol is sufficient in P2P video streaming. In order to present a comprehensive view of distortion, the dependency loss is defined. In this sense, according to the existing dependency graph, averaged loss of decoding of B or P frames is calculated, when the loss is due to dependencies among frames. Figure 8 shows the percentage of loss because of dependency among frames.

Here, about 80% of loss is due to the existing dependency between two frames where FEC protection is not employed. If all frames are protected by hybrid protocols i.e. FEC parity codes and ARQ method, dependency loss will reduce sharply to about 35%, which is good point for overcoming dependency loss. For a new sight, we can evaluate the buffer time and the averaged start time of playing the video stream in peers that participate in the overlay over wireless mesh networks. In this way, participated peers start playback as soon as the initial buffer time is finished and few seconds of the video stream is ready for playing.

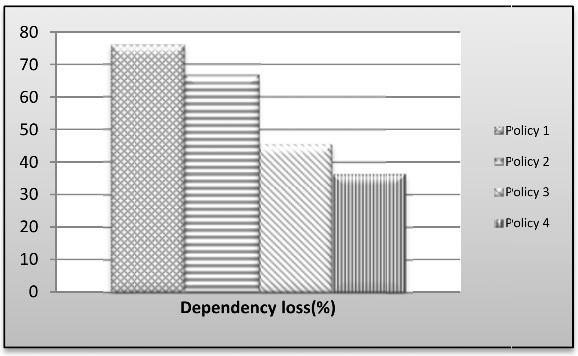

Fig. 8. Percentage of loss because of dependency between frames peer to peer video streaming over wireless mesh network

By evaluating the averaged time of starting the playback of video, we can see that if the end-to-end delay among peers and the introduced distortion decreased, the start time of playing will reduce too. As can be seen in the following figure, I frame protection by FEC parity codes additive to retransmission of loss frames would be enough for situation where loss probability is high (e.g. WMNs). But this method cannot increase the experienced quality of the video streaming as expected. In WMNs, it is better to protect all frames by FEC parity code in addition to retransmit the lost frames. Figure 9 shows the obtained results for the start playing time of different loss recovery policies in P2P video streaming over WMNs. Based on these figures, frame protection by hybrid protocols work well.

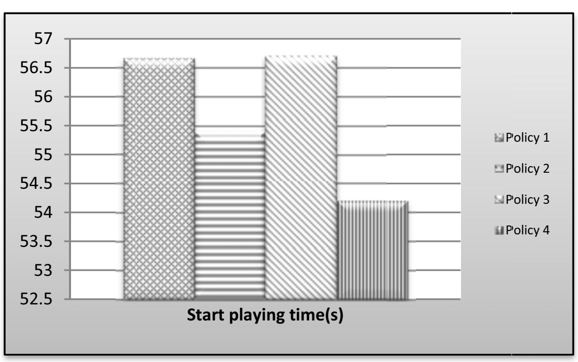

Fig. 9. Start playing time of different loss recovery policies in peer to peer video streaming over wireless mesh network

V. Conclusion

The motivation of this work was primarily to carry out a comprehensive study of different loss recovery policies of peer-to-peer video streaming in multi-hop and loss situations like wireless mesh network.

As the results show, protecting all parts of a GOP structure is important. However, it is better to protect only important parts of the GOP structure like I frames if the receiving time of video stream in the end users is important.

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References

[1] IEEE 802.11 Standard in IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical, IEEE.

[2] G. Hiertz, D. Denteneer, S. Max, R. Taori, J. Cardona, L. Berlemann and B. Walke, "IEEE 802.11s: The WLAN Mesh Standard," *IEEE Wireless Communications,* pp. 104-111, 2010, Vol.17.

[3] H. Xiaojun, L. Yong and K. Ross, "IPTV over P2P streaming networks: the mesh-pull approach," *Communications Magazine, IEEE,* pp. 86-92., 2008.

[4] J. Broberg, R. Buyya and Z. Tari, "MetaCDN: Harnessing 'Storage Clouds' for high performance content delivery," *Journal of Network and Computer Applications, Vol. 32,* pp. 1012-1022, 2009.

[5] N. Ramzan, H. Park and E. Izquierdo, "Video streaming over P2P networks: Challenges and opportunities," *Signal Processing: Image Communication,* pp. 401-411, 2012. 27(5).

[6] X. Lou and K. Hwang, "Quality of data delivery in peer-to-peer video streaming," *ACM Transactions on Multimedia Computing, Communications and Applications,* pp. 1-23, 2012, Vol.8.

[7] B. Akbari, H. R. Rabiee and M. Ghanbari, "Packet loss in peer-to-peer video streaming over the Internet," *Multimedia Systems,* pp. 345-361, 2008, Vol. 13(5).

[8] D. Moltchanov, "Service quality in P2P streaming systems," *Computer Science Review,* pp. 319-340, 2011, Vol.5(4).

[9] A. Montazeri, B. Akbari and M. Ghanbari, "An incentive scheduling mechanism for peer-to-peer video streaming," *Peer-to-Peer Networking and Applications,* pp. 257-278, 2012, 5(3).

[10] J. F. Buford, H. Yu and E. K. Lua, P2P Networking and Applications, Boston: Morgan Kaufmann, 2009, pp. 183-202.

[11] I. E. Richardson, The H.264 advanced video compression standard, Atrium: John Wiley & Sons, Ltd, 2010.

[12] M. Ghanbari, Standard Codecs, Image compression to advanced video coding, 3rd ed., The Institution of

Engineering and Technology, 2011, p. 372–385.

[13] H. Wu, M. Claypool and R. Kinicki, "Guidelines for Selecting Practical MPEG Group Of Pictures," in *IASTED International Conference on Internet and Multimedia Systems and Applications (EuroIMSA)*, Innsbruck, Austria, 2006.

[14] OMNeT++, Available from: http://www.OMNETPP.org/, 2012.

[15] H. Wehbe, G. Babonneau and B. Cousin, "Fast Packet Recovery for PULL-Based P2P Live Streaming Systems," in *The Second International Conference on Advances in P2P Systems*, AP2PS 2010.

[16] J. Peltotalo, J. Harju, L. Väätämöinen, I. Bouazizi, I. D. D. Curcio and J. V. Gassel, "Scalable Packet Loss Recovery for Mobile P2P Streaming," *Lecture Notes in Computer Science,* pp. 107-120, 2010. 60(74).

[17] S. Chung and H. Y. H. Jo, "A New Loss Recovery Algorithm for Increasing the Performance of TCP over Wireless Mesh Networks," in *IEEE International Conference on Advanced Information Networking and Applications*, 2012.

[18] I. Khalil and E. Weippl, "Innovations in Mobile Multimedia Communications and Applications," *New Technologies in Information Science Reference (IGI Global),* pp. 175-200, 2011.

[19] B. Akbari, H. R. Rabiee and M. Ghanbari, "Packet loss recovery schemes for peer-to-peer video streaming," in *International Conference on Network Services (ICNS2007*, Athens, Greece, 2007.

[20] M. Lindeberg, T. Plagemann, S. Kristiansen and V. Goebel, "Challenges and techniques for video streaming over mobile ad hoc networks," *Multimedia Systems,* pp. 51–82, 2011, vol. 17.

[21] "http://trace.eas.asu.edu/mpeg4/index.html/.," Arizona, A.S.U. Video Traces Research Group on MPEG-4, 2009. [Online].