Link Quality-Aware Overlay for Video Delivery over Wireless Mesh Networks

Quang Le-Dang, Jennifer McManis and Gabriel-Miro Muntean
Performance Engineering Laboratory, Network Innovations Centre, RINCE Institute
School of Electronic Engineering, Dublin City University, Ireland
Emails: quang.ledang2@mail.dcu.ie, jennifer.mcmanis@dcu.ie, gabriel.muntean@dcu.ie

***Abstract*— In this mobile-centric era, users expect ubiquitous data access at low cost to an ever increasing range of applications requiring high data connection speeds. A positive solution is the use of Wireless Mesh Networks (WMN) as they enable data access over a relatively large area at a modest cost and are relatively simple and flexible to deploy. Unfortunately, similar to other wireless multi-hop networks, WMN performance decreases with path length, background load, etc. In response to this, several approaches to manage traffic load have been proposed, including peer-to-peer solutions. However, in order to work efficiently, these solutions require not only availability awareness, but also knowledge about the conditions of the physical paths to peers and services. This paper first proposes a Multiplication Selector Metric (MSM) which addresses two major drawbacks of the traditional summation-based metrics for overlay peer selection: bottle-neck link identification and hop count behavior. MSM can work with any link quality - aware metric without any additional network overhead. Then, a cross-layer Wireless Link Quality – aware Overlay peer selection mechanism (WLO) is proposed, which uses MSM to identify the best peer for overlay content retrieval. Simulations show how the proposed peer-to-peer video delivery solution for WMN outperforms existing state-of-the-art solutions in terms of video delivery quality.**

***Index Terms*— Video delivery, Video on Demand, Wireless mesh networks, Link-aware overlay, Chord.**

I. INTRODUCTION

Wireless Mesh Networks (WMN) are last-mile access networks which are used for providing wireless connectivity and other services to various devices in a large coverage area. Typically, WMNs include two types of components: Mesh Routers (MR) and Mesh Clients (MC). MRs are stationary, power-unlimited and connected to each other to form a wireless backbone. Some MRs have wired connectivity to the Internet or other networks. MCs are user-devices which connect to the WMN through the MRs to gain access to the provided network resources. Lately, due to numerous real-life deployments in business premises, community or metropolitan areas, many researchers have proposed solutions to address some of WMNs limitation for increasing the achievable bandwidth, reducing interference [1] or supporting user or operator-specific applications such as VoIP, live video streaming, etc. [1] - [4].

This work is funded by the Higher Education Authority under the Programme for Research in Third-Level Institutions (PRTLI) Cycle 5 and co-funded under the European Regional Development Fund (ERDF).

In this paper, we consider video delivery, such as Video-on-Demand (VoD) on WMNs. For this type of application, Peer-to-Peer (P2P) resource sharing has been proved to be a promising solution with its scalable content distribution. However, for content delivery in a wireless multi-hop scenario, since the data rate between peers degrades sharply with the number of intermediate nodes between them [5] and is greatly affected by other factors such as load, obstacles, etc., it is important that the constructed peer-to-peer overlay is not only aware of the status and availability of peers, but also of the quality of the physical path taken by the data. Hence, a hash-based ID assignment such as that of Chord [6], CAN [7], Pastry [8] and Viceroy [9], well suited in wired networks, is not applicable to wireless scenarios where bandwidth is scarce and connectivity exhibits large variations.

In [10] the authors proposed an overlay network architecture over WMN and use a simple cross-layer approach of broadcasting-based lookups to all the network nodes to decrease lookup delay. While it is simple to implement, this flooding-based mechanism introduces excessive overlay messaging overhead and is not suitable for large-scale WMNs. Another approach to building overlays over wireless networks is to utilize CAN-based geographic hash table in which the IDs of data objects are hashed into geographic coordinates and the subsequent data related to these IDs is stored at the peer in the vicinity of this location [11]-[13]. However, since data is stored in some geographic coordinates possibly far from the source peer, updating the data introduces a significant amount of overhead across the network, which makes this class of protocols not scalable. In [14], the authors proposed a geographic ID mapping scheme which exploits location information of stationary MRs on WMNs to build a location-aware Viceroy-based overlay with a geographic ID mapping. [15] - [16] extended the same ID mapping scheme to Chord and proposed a cross-layer mechanism to reduce the lookup time. However, these schemes focus on the control plane of the overlay only and do not address the issue of improving the quality of data delivery.

In a P2P video delivery system, users can interact with the system by seeking within a video or jumping to another video. In [17]-[18], the authors proposed improved mechanisms to speed up the lookup process of seeking video segments by employing a grouping-based storage strategy

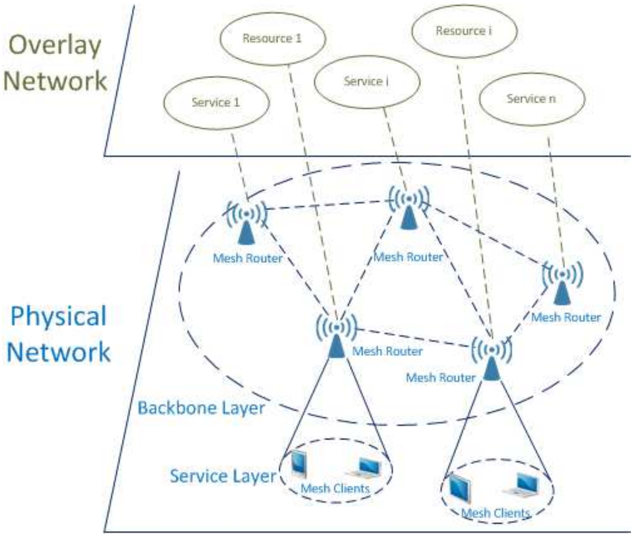


Figure 1: WLO network architecture.

[17] or by exploring overlay locality to build shortcuts over the Distributed Hash Table (DHT) network [18]. However, the P2P VoD system needs not only to provide fast lookup for the requested video segment but also to select from the peers that store the requested segment the one that can provide the best quality of service.

Recently, WILCO was proposed with a location-aware overlay [19] and a video segment seeking mechanism [20] in WMNs. The WILCO video segment seeking mechanism is based on WILCO multi-level geographical ID mapping to locate and retrieve the video segment from geographically closet peer in terms of hop count. However, this mechanism is unable to quantify the physical path quality and may try to obtain the video content from a closer peer via a worse path rather than from a further peer located on a much better path.

In order to improve the quality of video delivery, this paper first proposes **a Multiplication Selector Metric (MSM) for overlay peer selection**. The proposed metric selector overcomes two major limitations of the traditional summation-based metric without any additional networking overhead: bottleneck link identification and hop count behaviour. Then, **a Wireless Link quality-aware Overlay (WLO) peer selection mechanism** is proposed. Using a cross-layer approach, WLO selects the peer with the best physical path in terms of MSM among all the peers that possess the requested video content to retrieve it from. Simulation results show how WLO improves the quality of video retrieval in WMN in terms of average PSNR for different background loads and different degrees of topology incompleteness.

The rest of this paper is organized as follows. Section II describes MSM and the cross-layer WLO mechanism. In Section III, simulation results are presented and Section IV concludes the paper.

II. LINK QUALITY –AWARE OVERLAY

The proposed Wireless Link Quality – Aware Overlay (WLO) solution aims at improving the overlay video retrieval by selecting from among peers storing the content the one to which the requesting peer has the best quality path. For the peer selection metric, we first show that the basic summation metric does not work well in a large WMN network. A novel Multiplication Selector Metric (MSM) and a cross-layer mechanism are then proposed to overcome the drawbacks of the traditional summation metric for overlay peer selection.

A. Network Architecture

To support link quality awareness overlay for video distribution over WMNs, the two-layer architecture illustrated in Figure 1 is used. The service layer allows MCs to both share video content they have and use the one shared from other MCs. The backbone layer includes stationary, power-unlimited MRs running an overlay protocol such as that in [19] to form an overlay for video sharing support.

When performing video distribution, all videos are assigned unique keys according to the HASH algorithm [6] and are managed by the MRs. In order to support efficient video delivery in the peer-to-peer overlay, each video is divided into equal size segments with segment sequence number reflecting their playback order. During the distribution process, it is assumed that segments of the video will become available in several places within the WMN. The locations of the segments are registered and periodically updated at the MR which manages the video in a database with the following structure $[ID, S_i, L_i]$ where ID is the ID of the MR through which the MC connects to the network; S_i is the start segment sequence number stored at the node and L_i is the number of segments the node stores. In order to protect from single node failures, the successor of the MR which manages the *key* also stores and updates a copy of this database. For each requesting segment S_j, the MR searches its database and replies to the requesting peer with the set of peers that have the segment ($S_j \in [S_i, S_i + L_i]$). Base on this set, the requesting peer performs our WLO overlay peer selection mechanism to select the best overlay peer to retrieve the video segment.

B. MSM for Overlay Peer Selection

In order to achieve link level awareness on the overlay for peer selection, it is natural and straightforward to use a link quality aware routing protocol and then employ a cross-layer mechanism to get and compare the path metrics of all the destination peers to select the best peer. However, the following analysis shows that this simple mechanism is not efficient for overlay peer selection due to the nature of the summation-based metric.

According to [22], in spite of the metric diversity, in most recent routing protocols, the path metric is computed as a summation of all the link metrics along the path as in eq. (1)

$$M = \sum_{i=1}^{k-1} m_{n_i,n_{i+1}} \qquad (1)$$

In eq. (1) M is the path metric along a route of k nodes $n_1, \dots, n_k$ and $m_{n_i,n_{i+1}}$ is the link metric between node n_i and n_{i+1}.

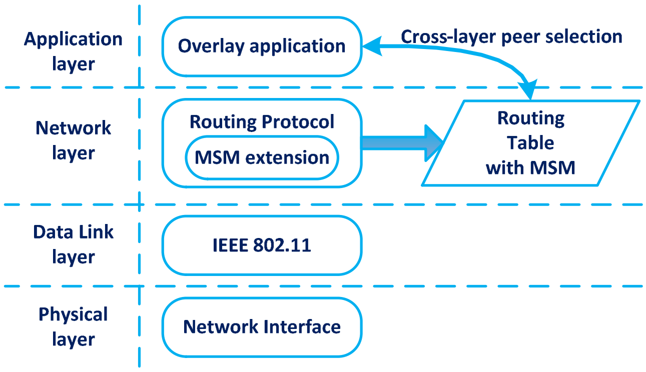


Figure 2: WLO cross-layer architecture.

Algorithm 1: WLO overlay peer selection mechanism using MSM

for each requested segment S_j
  Get the addresses of all overlay peers $\{d_1, d_2, \ldots, d_k\}$ which store the requesting video segment S_j.
  for each overlay peer $d_i \in \{d_1, d_2, \ldots, d_k\}$
    Perform cross-layer lookup for MSM_i in local routing table
  end for
  $MMS_{min} = \min\{MMS_i, i = 1, \ldots, k\}$
  Select overlay peer d_{min} with MSM_{min} to retrieve S_j.
end for

In comparison to other operators such as multiplication, this additive way of computing the path metric is well-suited for route selection to a single destination due to its ability to prevent small variations in one link along the path from significantly changing the whole accumulated metric as well as changing the whole route. As a result, the use of a summation –based metric increases the route stability by reducing the flipping between routes, especially when a link-aware metric is used which may vary quickly with time. However, when using this summation-based approach to evaluate the path quality to different destinations on different routes such as is the case of selecting the best peer from multiple overlay peers, this approach is not suitable for the two major reasons which will be discussed next.

First, the summation metric calculation **fails to identify the bottleneck** along the path. If a link quality – aware metric is used, one bad link along the path will severely affect the overall end-to-end service. However, the link metric of this bad link contributes only a small part to the summation-based path metric. As a result, this bottleneck can be easily buried by small fluctuations in metric calculation of the other links along the path. This weakness in bottleneck identification can be severe when selecting among multiple different destination peers as destinations with very different end-to-end path characteristics could have very similar metric values.

Second, the summation of link metrics, in fact, **imitates the hop-count behaviour**. Since the path metric increases after each traversed link, the accumulated metric can be recognized of the summation of hops along with the link-aware metrics as the weights. This hop-count behaviour tends to prefer the destination with the least-hop-path although of its path quality on the component links could be worse than that of a longer path. For example, if the Expected Transmission Count (ETX) metric [23] is used, a link metric of 1 implies a perfect link while a link metric of 2 implies that the packet loss on this link could be as high as 50%. As a result, a destination on a one-hop path with a 50% loss link would be preferred over a three-hop path with little or no loss.

Motivated by these observations, a MSM is proposed in which the metric for peer selection is calculated as a multiplication of all component link metrics as in eq. (2)

$$MSM = \prod_{i=1}^{k-1} m_{n_i,n_{i+1}} \quad (2)$$

In eq. (2) MSM is the Multiplication Selector Metric along a path of k nodes $n_1, \ldots, n_k$ and $m_{n_i,n_{i+1}}$ is the link metric between node n_i and n_{i+1}.

Since the link metrics are multiplied together, a bottle neck with a significantly higher link metric will boost the MSM by a few times and cannot be hidden by small fluctuations in metric calculation of the other links. In addition, the multiplicative way of calculating MSM mitigates the hop-count behavior of the traditional additive metric by emphasizing the quality of the links along the path rather than the path-length. As a result, a peer on a longer path with very good link quality will be preferred over one on a shorter path but with bad link quality.

It is noted here that the use of a multiplicative metric for underlay routing has already been proposed in the literature (e.g. [24].) However, since the aim of underlay routing is to resolve the best path to a pre-determined destination, multiplying small changes in link metrics could change the whole route virtually with every routing update, making routing unstable. Our objective is different, i.e., choosing the best overlay peer for content retrieval (and hence possibly different destinations). For this purpose we suggest the use of multiplicative metric for overlay peer selection but still use additive metric, as is, for underlay routing. The simulation results in section III suggests that the proposed approach is well suited to overlay peer selection. Moreover, since the proposed solution uses MSM for selecting the best overlay peer and use the underlay routing protocol as is with the traditional (summation-based) metric that came along with the routing protocol, the proposed solution does not have to tie to any link-aware routing protocol or metric.

Furthermore, in comparison with other approaches which either introduce additional networking overhead, are incompatible with the existing standard routing protocols, or are very computational intensive, MSM introduces a negligible additional computational processing and no extra networking overhead. These advantages make MSM easy to implement and integrate into any existing WMNs.

C. WLO Overlay Peer Selection Mechanism

In order to realize link quality - aware overlay peer selection using MSM, the MSM calculation is integrated into the WMN routing protocol. This MSM extension of the routing protocol calculates MSM for each of the best routes

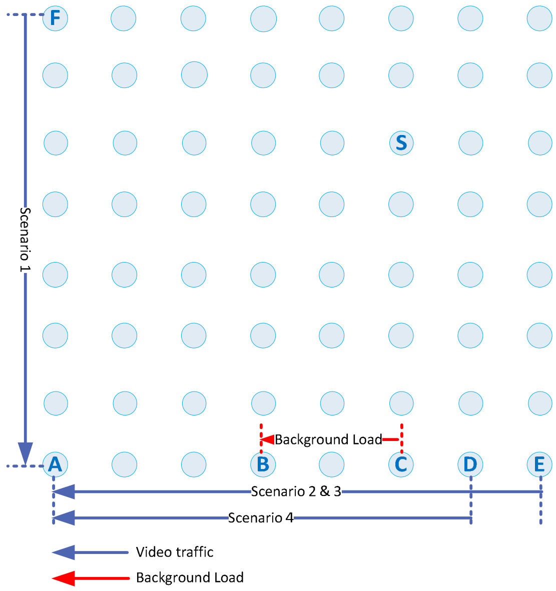


Figure 3: Simulation topology.

selected by the protocol and inserts a MSM field into the routing table associated to the corresponding route.

When the overlay application wants to select the best peer to get the video segment from, it performs a cross-layer peer selection in which it retrieves all the MSM values of all the destination peers with the requested video segment from its routing table. Based on the acquired information, the overlay application selects the peer with the lowest MSM to retrieve the video content from. WLO cross-layer architecture is illustrated in Figure 2 and WLO overlay peer selection mechanism using MSM is illustrated in Algorithm 1.

III. Simulation Based Testing

The performance of the proposed WLO is evaluated using Network Simulator 3 [25]. The simulated topology consists of $N = 64$ MRs arranged in an 8x8 grid. The distance between two adjacent MRs is set to 100m as depicted in Figure 3. In the simulations, all MRs are equipped with IEEE 802.11b radios and the OLSR-ETX routing protocol is used to perform routing and enable data transfer. Each simulation is repeated 10 times and the results are averaged. First, some simple scenarios are investigated to illustrate the effectiveness of MSM, then, more thorough simulation results are presented to show WLO's benefits. Throughout our simulations, video retrieval quality is evaluated using the Peak Signal-to-Noise Ratio (PSNR) and packet loss. The video quality retrieval performance of WLO is compared to that of WILCO, QUVoD[17] and a server-only solution (*Server*).

A. Illustration of MSM Effectiveness in Simple Scenarios.

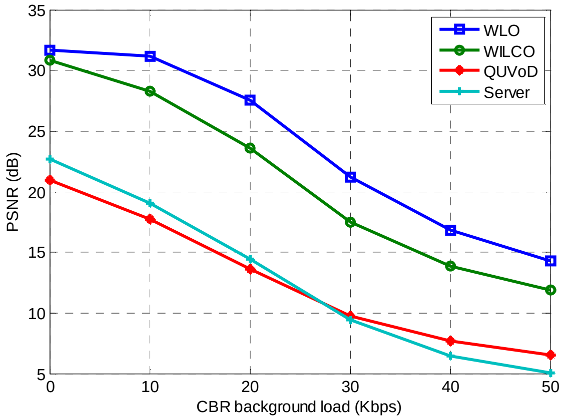
First, the effectiveness of MSM over the traditional summation metric (ETX) is illustrated in four simple scenarios. In these simple scenarios, MRs A, D and E in Figure 3 are the requesting peer and the two serving peers storing the requested video segment, respectively. Background traffic load, if it exists, is from B to C. The four scenarios include video streaming at different path length and background load along with the traditional summation metric and MSM. The PSNR results and packet loss are summarized in Table 1. The video performance is evaluated by simulating streaming of one real video segment using a trace file. The video bit rate is 341Kpbs, is 10 seconds long and is about 0.44MB in size.

Table 1: Illustration of MSM effectiveness in four simple scenarios.

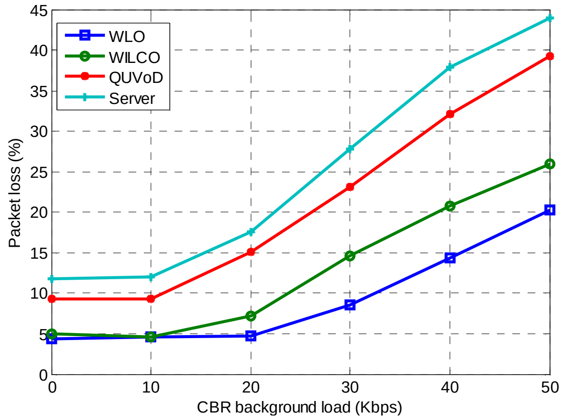
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Req. Peer	A	A	A	A
Serv. Peer	F	E	E	D
Background Load	No Load	50 Kbps	1 Mbps	1 Mbps
PSNR	29.49 dB	28.46 dB	5.68 dB	6.70 dB
Packet loss	4.77%	5.87%	49.59%	30.80%
ETX	11.00	11.20	11.81	10.23
MSM	29.26	30.38	46.41	42.36

In Table 1, scenario 1 is used as a baseline for comparison with the other scenarios. Scenario 2 and 3 present PSNR and packet loss performance of the same network path length as with the baseline scenario, from A to E, but under different background loads. It is observed that in comparison to scenario 1, both the PSNR and packet loss become worse in scenario 2 and 3 due to the increase of background load levels. However, it is important to remark that the ETX metrics vary very little in the second and the third scenario in comparison with the baseline scenario. The ETX's and packet loss figures in Table 1 illustrate that while the packet loss is very high in scenario 3, when the background load in the intermediate nodes is high, the ETX metric in this scenario is less than 10% higher than that of scenario 1 with a load-free path. If there were some small variations in metric measurement on scenario 1, this insignificant difference in the ETX summation-based metric could be easily buried and a peer selection using an underlay summation-based could be a bad choice. As a result, an overlay peer selection using a summation metric directly from the routing table could select the peer with the bad link quality for content retrieval due to the bottleneck and the hop-count behaviour which were described earlier in this chapter. On the other hand, it can be seen from Table 1 that the MSM metric reflects very well the path quality in each of the first three scenarios, having a significant higher MSM in scenario 3 in comparison with scenarios 1 and 2.

Furthermore, in scenario 4, both the traditional summation ETX metric and MSM are investigated when the serving peer is on a path with one hop less than the other scenarios, but with a very high background traffic load on the intermediate nodes along the path. It is important to see from Table 1 that while the PSNR and packet loss performance is very bad in this scenario due to the high load of background traffic on the intermediate nodes, the ETX is lower than that of all the other three scenarios. This is due to the hop count behaviour mentioned earlier that the traditional summation metric imitates the hop count metric and increases after each hop along the path. As a result, a longer but much better path



a. PSNR comparison.



b. Packet loss comparison.

Figure 4: PSNR and packet loss comparison with different background loads.

is not preferred over a shorter, but heavily loaded one. On the other hand, in this scenario, the MSM metric continues to reflect the path quality very well, having a significantly higher value than in both scenarios 1 and 2.

These scenarios confirm our claim on the effectiveness of MSM in choosing the best overlay peer to retrieve the content from.

B. Video Retrieval Performance with Different Levels of Background Load

We further evaluate the performance of the proposed overlay peer selection using WLO with different background traffic loads. The video retrieval performance of WLO is compared against WILCO, QUVoD and Server. To simulate background load, $N/4$ constant bit rate (CBR) UDP streams are generated between $N/2$ randomly selected source and destination peers. The load of each of the background traffic streams is varied from 0 (no load) to 50Kbps.

In our simulations, real video trace files are used to simulate the retrieval of three video segments ($S = S1, S2, S3$ on each of the overlay peers. The video descriptions are the same as in III. A. The number of replicas for each video segment is three. The video server is denoted by S in Figure 3 and contains all the three video segments. The other segments are randomly distributed across the network.

Figure 4a illustrates the video retrieval PSNR performance of the four schemes. This figure shows that for all the background load levels, the PSNR values achieved by WLO and WILCO are two times higher than that of the other two schemes with about 10dB difference. It is important to note that the difference in PSNR of QUVoD and Server is negligible across all the observed background loads. This fact clearly shows that on a wireless multi-hop network, deploying P2P services without considering the physical topology is not better than using a single server in terms of the quality of content retrieval. Figure 4b confirms this result, showing that WLO and WILCO can significantly reduce the packet loss by at least 50% compared to the other two schemes.

In comparison with WILCO, with no background load, the PSNR values of WLO and WILCO are similar. However, when the background load increases, the PSNR of WILCO decreases quickly, while WLO retains a very high PSNR with a slower decreasing trend. Throughout all the background loads, WLO outperforms WILCO by a good 4dB difference in PSNR. This result can be explained by the fact that WLO can intelligently choose the best peer with the lightest load path even on a longer path while WILCO concentrates on the physically nearest peer regardless of the path load. Figure 4b further confirms this result. While the packet loss of WILCO generally increases with the background load, WLO packet loss remains under 5% up to 20Kbps. At higher background loads, the link quality aware overlay peer selection mechanism of WLO enables it to choose the peer with a better path and keep the packet loss lower than WILCO.

C. Video Retrieval Performance in Incomplete Topologies

In real-life deployments, it is ideal to have a complete grid topology as in Figure 3. However, this complete topology is hard to achieve due to several reasons such as cost, obstacles or difficulties in installation. In this part, video retrieval performance of WLO, WILCO, QUVoD and Server are compared in incomplete topologies by turning off some of the MRs. The MRs which are turned off are uniformly randomly distributed across the physical topology. The degree of incompleteness is 5%, 10% and 20%; anything larger than 20% would partition the original topology into disconnected parts. In each case, ten different topologies are tested and the results are averaged. The background traffic load is 10Kbps and all the other assumptions are kept the same as in Section III. B.

Figure 5 shows the PSNR comparison of the four schemes in incomplete topologies with the x axis represents the degree of topology incompleteness at 0% (complete topology), 5%, 10% and 20%, respectively. It is illustrated that the retrieved video quality degrades with the incompleteness of the topology due to suboptimal paths. However, while WLO retains a very high PSNR even when 20% of the MRs are off, PSNR values for the other three schemes decrease sharply. In comparison to the PSNR in a complete topology, WLO for a 20% topology

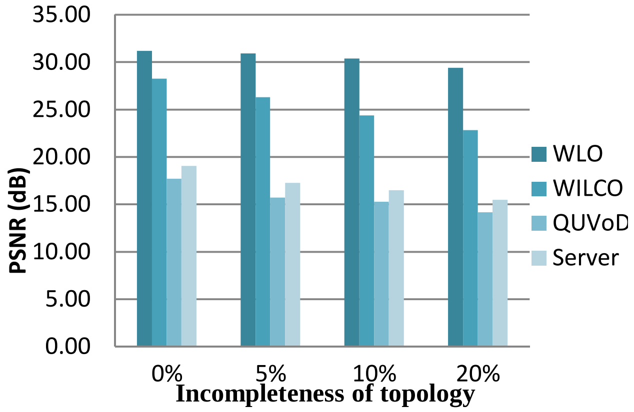


Figure 5: PSNR comparison in incomplete topologies.

incompleteness decreases by 5% only, while that of the other three schemes degrade by roughly 20% in similar situations.

From Figure 5, it is interesting to see that the PSNR of WILCO is the most sensitive to the topology incompleteness. This can be explained by the fact that the WILCO segment seeking algorithm assumes a complete topology so the peer selection could be worse even in terms of hop count in incomplete topologies.

IV. CONCLUSION

This paper proposed WLO, a Link Quality – Aware Overlay for Video delivery over Wireless Mesh Networks. The proposed scheme uses MSM, a novel Multiplication Selector Metric, which unlike the traditional summation metric, detects bottleneck links and does not resemble a hop count behavior. A cross-layer overlay peer selection mechanism is proposed, using MSM to select the best peer for overlay content retrieval. Our simulation results show that WLO greatly reduce the packet loss and significantly improves the video quality retrieval by up to two times in terms of PSNR with different background loads and different degrees of topology incompleteness in comparison with other solutions.

REFERENCES

[1] D. Benyamina, A. Hafid, M. Gendreau, “Wireless Mesh Networks Design – A Survey”, IEEE Communications Surveys and Tutorials, Vol. 14 (2), pp. 299-310, 2012.

[2] G.-M. Muntean, P. Perry, L. Murphy "Objective and subjective evaluation of QOAS video streaming over broadband networks" *IEEE Transactions on Network and Service Management*, Vol. 2 (1), pp. 19-28, 2005

[3] M. Kennedy, H. Venkataraman, G. Muntean, "Battery and stream-aware adaptive multimedia delivery for wireless devices" *IEEE Local Computer Networks*, pp. 843-846, 2010

[4] G.-M. Muntean, P. Perry, L. Murphy, "A comparison-based study of quality-oriented video on demand" *IEEE Transactions on Broadcasting*, Vol. 53 (1), pp. 92-102, 2007.

[5] P. Gupta, P. R. Kumar, “The Capacity of Wireless Networks”, *IEEE Transaction on Information Theory*, Vol. 46 (2), pp. 388-404, 2000.

[6] I. Stoica, R. Morris, D. L. Nowell, D. R. Karger, M. F. Kaashoek, F. Dabek, H. Balakrishnan, “Chord: A Scalable Peer-to-Peer Lookup Protocol for Internet Applications”, *IEEE Transactions on Networking*, Vol. 11, pp. 17-32, 2003.

[7] S. Ratnasamy, P. Francis, M. Handley, R. Karp, S. Shenker, “A Scalable Content-Addressable Network”, *Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications*, pp. 161-172, 2001.

[8] A. Rowstron, P. Druschel, “Pastry: A Scalable, Decentralized Object Location and Routing for Large Scale Peer-to-Peer System”, *IFIP/ACM Middleware*, pp. 329-350, 2001.

[9] D. Malkhi, M. Naor, D. Ratajczak, “Viceroy: A Scalable and Dynamic Emulation of the Butterfly”, *Symposium on Principles of Distributed Computing*, pp. 183-192, 2002.

[10] G. Ding, J. Vicente, S. Rungta, D. Krishnaswamy, W. Chan, K. Miao, “Overlays on Wireless Mesh Networks: Implementation and cross-Layer Searching”, *IEEE International Conference on Management of Multimedia and Mobile Networks and Services*, pp. 171-182, 2006.

[11] P. Desnoyers, D. Ganesan, P. Shenoy, “TSAR: A two tier sensor storage architecture using Interval Skip Graphs”, *International Conf. on Embedded Networked Sensor Systems*, pp. 39-50, 2005.

[12] S. Ratnasamy, B. Karp, S. Shenker, D. Estrin, R. Govindan, L. Yin, F. Yu, “Data-centric storage in sensornets with GHT, A Geographic Hash table”, *Mobile Networks and Applications*, Vol.8 (4), pp. 427-442, 2003.

[13] O. Landsiedel, S. Gotz, K. Wehrle, “Towards Scalable Mobility in Distributed Hash Tables”, *IEEE International Conference on Peer-to-peer Computing*, pp. 203-209, 2006.

[14] L. Gallucio, G. Morabito, S. Palazzo, M. Pellegrini, M. E. Renda, P. Santi, “Georoy: A location-aware enhancement to Viceroy peer-to-peer algorithm”, *Computer Networks*, Vol 51(8), pp 1998-2014, 2007

[15] S. Burresi, C. Canali, M. E. Renda, P. Santi, “MeshChord: A Location-Aware, Cross-layer Specialization of Chord for Wireless Mesh Networks”, *IEEE International Conference on Pervasive Computing and Communications*, pp. 206-212, 2008.

[16] C. Canali, M. E. Renda, P. Santi, S. Burresi, “Enabling Efficient Peer-to-Peer Resource sharing in Wireless Mesh Networks”, *IEEE Transaction on Mobile Computing*, Vol. 9 (3), pp. 333-347, 2010.

[17] C. Xu, F. Zhao, J. Guan, H. Zhang, G.-M. Muntean, “QoE-driven User-centric VoD Services in Urban Multi-homed P2P-based Vehicular Networks”, *IEEE Transaction on Vehicular Technology*, Vol. 62 (5), pp. 2273-2289, 2013.

[18] D. Wang, C. K. Yeo, “Exploring Locality of Reference in P2P VoD Systems”, *IEEE Trans. on Multimedia*, Vol. 14 (4), pp. 1309-1323, 2012.

[19] Q. Le-Dang, J. McManis, G. M. Muntean, “Location-Aware Chord-based Overlay for Wireless Mesh Networks”, *IEEE Transaction On Vehicular Technologies*, Vol. 63 (3), pp. 1378-1387, 2014.

[20] Q. Le-Dang, J. McManis, G. M. Muntean, “User Location-Aware Video Delivery over Wireless Mesh Networks”, *IEEE Int. Symposium on Broadband Multimedia Systems and Broadcasting*, pp. 1-6, 2013.

[21] Q. Le-Dang, J. McManis, and G.-M. Muntean, “A location coordinate-based video delivery scheme over wireless mesh networks”, *ACM/Springer Wireless Networks*, Vol. 21, 2015.

[22] S. Misra, S. C. Misra, I. Woungang, “Guide to Wireless Mesh Networks”, *Computer Communications and Networks*, pp. 199-230, Springer London, 2009.

[23] D. S. J. De Couto, D. Aguayo, J. Bicket, R. Morris, “A High-Throughput Path Metric for Multi-Hop Wireless Routing”, *International Conference on Mobile Computing and Networking*, pp. 134-146, 2003.

[24] D. Passos, C. V. N. de Albuquerque, M. E. M. Campoista, L. H. M, K. Costa, O. C. M. B. Duarte, “Minimum Loss Multiplicative Routing Metrics for Wireless Mesh Networks”, Journal of Internet Services and Applications, Vol. 1 (3), pp. 201-214, 2011.

[25] Network Simulator 3 - http://www.nsnam.org/