Proximity-based video delivery architecture for LTE networks

S. Singh, N. Saxena✉, A. Roy and P. De

Out of total mobile data traffic, mobile video traffic accounts for 55%. Massive increase in mobile video traffic trend and simultaneous proliferation in smart devices strains the expanding cellular network that triggers the demand to retain the quality of video. To fortify this challenge, proximity-based video delivery architectures are put forward. Four novel architectures are proposed depending on the location of the users, which tends to reduce load on video servers and core network elements. Through realistic simulation results, it is proved that the present system procures up to 69.15% increase in throughput, 40.81% decrease in end-to-end delay and 92% reduction in jitter as compared with the traditional 4G long term evolution (LTE)/LTE-A system. The proposed video dispatching architecture outperforms the existing strategy by 53% and increases the cell capacity up to four times compared with the current 4G LTE/LTE-A networks.

Introduction: Exponential growth in the hardware and software technologies results in proliferation of smart devices in the network. There will be around 2.56 billion smart devices in the network by 2018 [1], constituting 94% of mobile data traffic [1]. This is because of refinement of cellular network each year. The 4G long term evolution (LTE) connection is expected to constitute 51% of total mobile traffic with almost double speeds by 2018 [1]. Rapid development and expansion in cellular network and increasing smart devices result in the expansion of mobile video traffic which is expected to constitute 69% of the total global cellular networks by 2018 [1]. From the past few years, video watching trend is changing. Earlier users used to watch videos on major websites like Youtube, Dailymotion and so on where the content is published by the content provider. The trend shifted to watching videos on mobile applications like vine, instagram, facebook and so on where the content is published by content provider as well as the users. Recently, due to the advent of applications like Meercat, Periscope and so on, era of live video streaming gained popularity. A user can record the video and share it live with the users in his vicinity or users far off. Video content is generated, shared and downloaded by the users itself. Nowadays, 92% of mobile video spectators share the video with the other [1] out of which live video dominates video on demand [1]. However, the quality of service (QoS) requirements for live streaming is demanding. Especially with users spread across the globe, it is challenging to deliver content in a timely manner. Let us consider a scenario where a user attending a live concert is streaming the event recorded using her smartphone to a group of friends who are spread across different locations. Some receivers are within the same cellular neighbourhood, but others may be across the globe. The goal is to deliver the video to all participants in the sharing, in sync, and with the minimal time lag with respect to the live content. Viewers in the close neighbourhood (viz. within the same cell of the network) can receive the video stream faster than the globally distant viewers. To fortify this challenge, we propose proximity-based four live video delivery architectures for LTE networks based on the location of the users. Depending on the relative location of the users, our proposed proximity-based video architectures bypass the main video server and associated network elements. Video packets traverse from the source to the receiver from the nearest possible network node which is common in between the source and the receiver. This may call for merging of content providers and network operators in the near future for the efficient video delivery. Simulation results of our proximity-based four architectures depict considerable increase in throughput by 69.15%, decrease in end-to-end delay by 40.81% and reduction in jitter by 92% as compared with the traditional cellular networks. Our proposed framework is compared with the already existing strategy in [2]. Our proposed video dispatching architecture outperforms the existing strategy by 53%. Moreover, our proposed live video delivery architectures escalate the cell capacity (i.e. simultaneous video connection support) up to four times compared with the current 4G LTE networks. This mitigates the challenge to dispatch the live video to the users synchronously across the globe with minimum possible lag. Several existing research works in this area have investigated the idea of co-operative streaming or a mobile node acting as a middle-ware for sharing a video with another device. User-generated short video sharing with globally located users is contemplated in [3]. The authors curtail the inter-cloud data transfer cost by 5/6 times with 12% degradation of user preference. Traffic offloading assisted by social network services (SNS) via opportunistic sharing (TOSS) [4] architecture proposes to explore an idea of offloading traffic by utilising social network services and opportunistic sharing by mobile devices. It decreases the cellular traffic by 86.5% and assures the access delay necessity of all the clients.

Our proposed architectures: Fig. 1 shows the overall 3rd Generation Partnership Project (3GPP) LTE network architecture with a set of omni-cell evolved Node B (eNBs). In legacy, 4G systems video traffic typically traverses all the way through the video server, via eNB and core networks (EPC) as shown in Fig. 1. While a typical LTE macrocell capacity is a few hundred users, a single EPC and a video server typically serves around a few thousands of cells. Thus, even with gigabit Ethernet links, the video server and the core network will soon be a bottleneck for mobile video transmission. Increasing popularity of live mobile video sharing through applications or social networking websites, peer-to-peer video sharing (e.g. small video clips) will make the problem even worse.

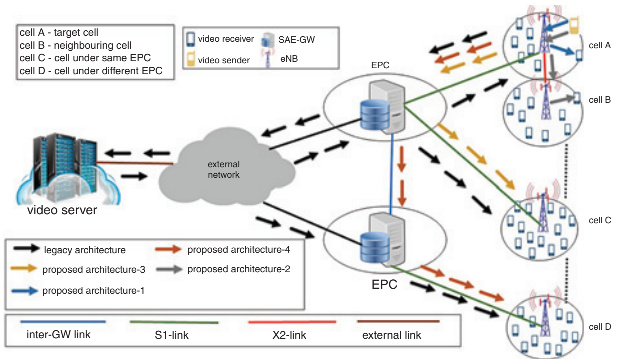

Fig. 1 *Overall 3GPP LTE architecture and our proposed architectures*

Table 1: Network and video traffic parameters

Video size	70 MB
Packet size	1000 B
Send inter-arrival time	exp (5 ms)
X2-link rate	40 Mbit/s
S1-link rate	30 Mbit/s
Effective GW–GW link rate per eNB	14 Mbit/s
Effective GW–server link rate per eNB	10 Mbit/s
Number of transmitters	1, 2, 3
Number of receivers	10, 20, 50, 100, 150, 200
Input traffic rate	1.6 Mbit/s
Air interface uplink rate	50 Mbit/s
Air interface downlink rate	100 Mbit/s

To alleviate this problem, we propose and design a more efficient video delivery architectures over LTE systems. Depending on the location of the video receivers, we propose to reroute the video packets directly from the nearest network node, which is common between the video source and receivers. This will bypass the network elements and links, thereby significantly reducing the load on the video server and core network. More precisely, we explain the four proposed architectures below:

(i) *Architecture-1:* If the video source and the video receivers are in the same cell, the video packets will follow the route: User equipment (UE) (source) <-> eNB (common between source and receiver) <-> UE (receiver). This will result in significant load reduction in core network and video server, thereby improving the video packet latency, jitter, throughput and cell capacity. We demonstrate this as architecture 1 in Fig. 1.
(ii) *Architecture-2:* If the video source and the video receivers are not in the same cell, but in a nearby cell. The video packets will follow the route: UE (source) <-> Source ENB <-> Target eNB <-> UE (receiver). X2 interface between source and target eNB is explored. This improves the video packet delay, jitter, throughput and cell capacity. We highlight this as architecture 2 in Fig. 1.
(iii) *Architecture-3:* On the other hand, if the video receivers are in a distant cell (same EPC), with no direct X2 connectivity, we propose

to explore LTE's S1 interfaces of the eNBs. The video packets will follow the route: UE (Source) <-> Source eNB <-> System Architecture Evolution-Gateway (SAE-GW) (common between source and receiver) <-> Target eNB <-> UE (receiver). It avoids the external network, relieve the video server and achieve some improvements in video packet latency, jitter, throughput and cell capacity. Fig. 1 points this as architecture 3.

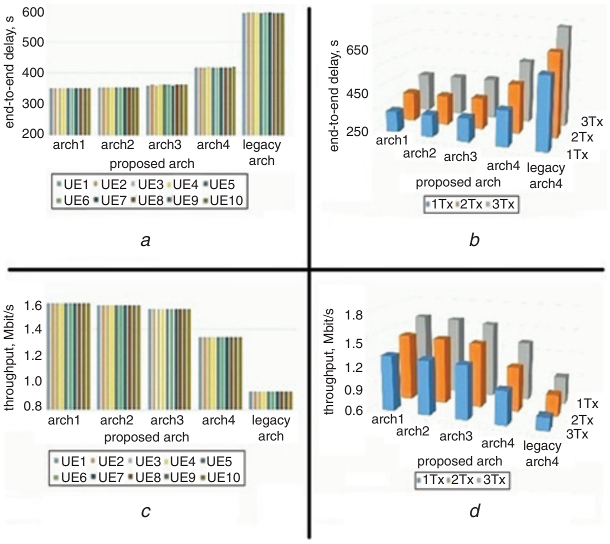

Fig. 2 *Simulation results in terms of performance metrics, i.e. end-to-end delay and throughput*

a Per user end-to end delay for each architecture
b Average end-to end delay for each architecture for different number of Tx
c Per user throughput for each architecture
d Average throughput for each architecture for different number of Tx

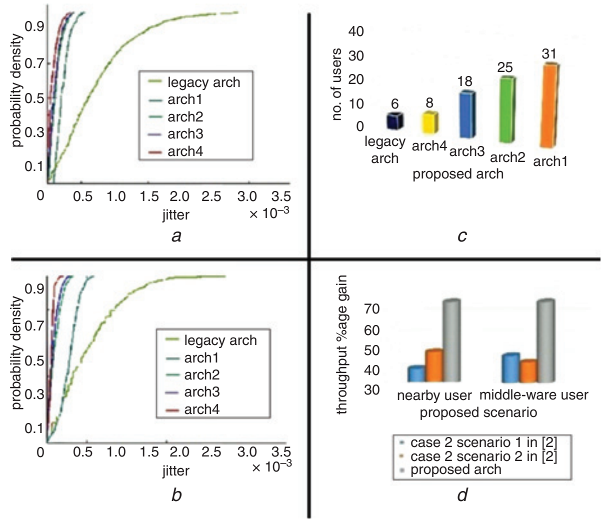

Fig. 3 *Simulation results in terms of performance metrics, i.e. throughput, jitter and network capacity*

a Jitter cumulative distribution function (CDF) plot for each architecture (delay difference)
b Jitter CDF plot for each architecture (mean deviation)
c Capacity of each architecture
d Throughput comparison with [2]

(iv) *Architecture-4:* Finally, if the video receivers are in a very distant cell across different EPCs, we propose to explore LTE's S1 interfaces as well as inter-EPC (core network) links as UE (Source) <-> Source eNB <-> Source SAE-GW <-> Receiver SAE-GW <-> Target eNB <-> UE (receiver). Thus, although the video receivers are in a very distant cell (in a different EPC), we can still avoid the external network, relieve the video server and achieve some performance improvements. Fig. 1 exhibits this as architecture 4.

Results: In this section, first we mention network and video traffic parameters in Table 1. Subsequently, we discuss our simulation results in terms of four performance metrics, i.e. end-to-end delay, throughput, jitter and network capacity.
End-to-end delay: Fig. 2*a* shows the per user end-to-end delay for each architecture, whereas Fig. 2*b* illustrates end-to-end delay with different number of transmitters. Link saturates faster in case of legacy architecture as compared with the proposed architectures. Proposed architectures bypass the video server and the associated links due to which there is about 40.81% decrease in end-to-end delay as compared with the legacy architecture.
Throughput: Fig. 2*c* presents per user throughput for each architecture followed by depiction of throughput with variable number of transmitter in Fig. 2*d*. Our proposed architecture renders 69.15% increase in throughput due to prolonged route of video packet in case of legacy architecture as compared with proposed architectures. Fig. 3*d* presents percentage gain in the throughput of our proposed architecture and wifi offload technique in [2]. Our proposed architecture outperforms existing technique in [2] by 53%.
Jitter: Figs. 3*a* and *b* delineate the CDF plot for jitter (delay difference and mean deviation). There is about 93% decrease in the jitter due to reduction in network route of video packets in case of proposed architectures.
Network capacity: Fig. 3*c* describes the inclination in network capacity of proposed architectures. Our proposed architectures can support up to four times more simultaneous video connections as compared with legacy architecture without disturbing the video quality.

Conclusion: In this Letter, we put forward four efficient proximity-based video dispatching architectures for LTE networks.
Discussions: We proposed to traverse the video packets from the source to the receiver depending on the location via nearest network node which is common in between the source and the receiver. Our video dispatching framework tends to reduce load on video servers and core network elements by bypassing the network elements depending on the location of the video source and the receivers. Our results clearly show the effectiveness of our proximity-based live video dispatching architectures. Our architectures will improve the QoS of live video sharing among the users with minimal time lag. They also enhance the support of simultaneous video connections in the network without disturbing the video quality.
Gains: Our simulation results show considerable increase in throughput by 69.15%, decrease in end-to-end delay by 40.81% and reduction in jitter by 92%. Our proposed architecture is compared with the already existing strategy in [2]. Our video dispatching architecture outperforms the existing strategy by 53%. Also, there is escalation in capacity of the cell. In our proposed system, simultaneous video connections support increases up to four times than the current 4G LTE networks.

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One or more of the Figures in this Letter are available in colour online.

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