link, and through vehicular mobile devices as ferries. As it's shown in Figure 1, the video chunks can be stored in RAM of those mobile devices that travel by cars from right to left. Then, they will be transferred to the cell B when carrying devices enter to this cell's coverage zone. This data delivery path is a delay tolerant link and transmitted data will undergo an extraordinary delay. This delay is related to the average speed of cars and distance between two cells.

2.2 Video Transfer and Playout

Let T_d be the maximum acceptable and expected delay of video chunk transmission from media server to the streaming client using video ferrying. This includes delay of ferrying, buffering in median nodes, propagation and so on. When client sends a request for video file, the cellular network core (for example EPC in 3GPP) is aware of this request and creates two sessions from a gateway to video server and client. In order to keep quality of experience (QoE) in a satisfied level, the initial chunks of video is transferred with conventional protocols through low capacity link while rest of video file are sent by ferrying. Let T_i be the initial length of video which is received by reliable path conventionally. In order to avoid playout interruptions, T_i should be greater than T_d.

2.3 Fault Tolerance Mechanism

The ferrying path is not perfectly reliable because the cars may be stopped or turn to unexpected path and RAM resources may be wiped out by user applications. If a video chunk's delivery was failed or interrupted, it should be requested through reliable low capacity link instantly for another transmission by gateway where ferried video chunks are cached due to reliability. We consider two approaches to deal with this problem. First, the gateway can check video chunk's delivery by client after a deadline (more than T_d) and resend non received ones. Alternatively, client has a critical given time, T_f, to check availability of future chunks before playout. T_f should be as sufficient as the client can send request to the gateway and receive the missed chunk. We recommend the second approach which decrease gateway load. In this way, no acknowledgment is needed in ferrying link and the reliability is provided by application layer. The conventional transport protocols TCP and UDP can be used for low capacity link and ferrying link transmissions respectively.

3. ACHIEVED EFFICIENCY

We assume the streaming client watches the video completely. The offloading efficiency will be:

$$efficiency = \frac{(total\_video\_lenth - T_i)(1 - P_l)}{total\_video\_lenth} \quad (1)$$

where P_l is the loss probability of video chunks during ferrying. This simple equation shows that this approach is more efficient with longer video clips and for short length video (less than T_i) there will be no efficiency if we want to avoid any additional delay that effects QoE. In a real-world speed measurement campaign, the average speed on seven major routes across Sydney was between 30-35 km/h in 2010 [8]. This shows that if 2 km is kept as maximum distance between source and sink small cells in the network design, T_d will be about 3.5-4 minutes and T_i can be chosen 5 minutes as the worst case.

Table 1: Offloading efficiency

Video Length \ Distance	500 m	1 km	2km
10 min	72%	64%	51%
30 min (TV shows)	81%	78%	73%
100 min (movies)	84%	83%	81%

($P_l = 0.15$, average speed = 36 km/h)

The average length of on-line video have been increasing during recent years. In U.S. it has risen from 2.9 minutes in 2010 to 5.1 minutes in 2014 [4]. While the most of online videos are shorter than 5 minutes, the major video traffic belongs to long video streams. For example, in U.S. while number of YouTube streams is about 50 times more than Netflix, Netflix is largest source of traffic and accounts for over 33% in contrast with 15% share of YouTube [2]. This is because of Netflix's much longer videos such as 30 minutes TV shows and even longer series and movies and also its higher video quality. Table 1 shows potential offloading efficiency for some different situations.

4. VIDEO POPULARITY AND CACHING

When a popular video is being watched by several clients in a short time window, it can be cached for saving link's bandwidth. Caching can be done by gateway or by all or selected small cells locally and even user devices can be considered as caching helper [6]. Caching in small cells needs storage hardware and results additional cost, though its requirements and efficiency has to be studied further.

5. SUMMARY AND FUTURE WORK

In this paper we proposed a low cost video streaming approach for cellular network which can target video on demand market for long duration videos such as movies and TV series. Impacts of user behaviour in playing video file, predictability of user mobility and relaying data in road traffic congestion are subjects of our future works.

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