Improving the Expected Quality of Experience in Cloud-Enabled Wireless Access Networks

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Introduction

New Mobile Devices go online every day, Cellular Spectrum is limited, and Wireless Access Points have limited capacity.

It is anticipated that mobile video traffic will increase 13-fold from 2014 to 2019, reaching 17.5 Exabyte's per month and accounting for nearly three-fourths of the world's mobile data traffic by 2019 [1].

Show how SDN and Cloud technologies deployed at a wireless edge network can improve the QoE of users. If service providers can optimize the QoE, they can potentially find the means to satisfy their existing customers while gaining resources to support new customers.

[1] Cisco, "Cisco Visual Network Index: Global Mobile Traffic Forecast Update 2014–2019," Feb 2015.

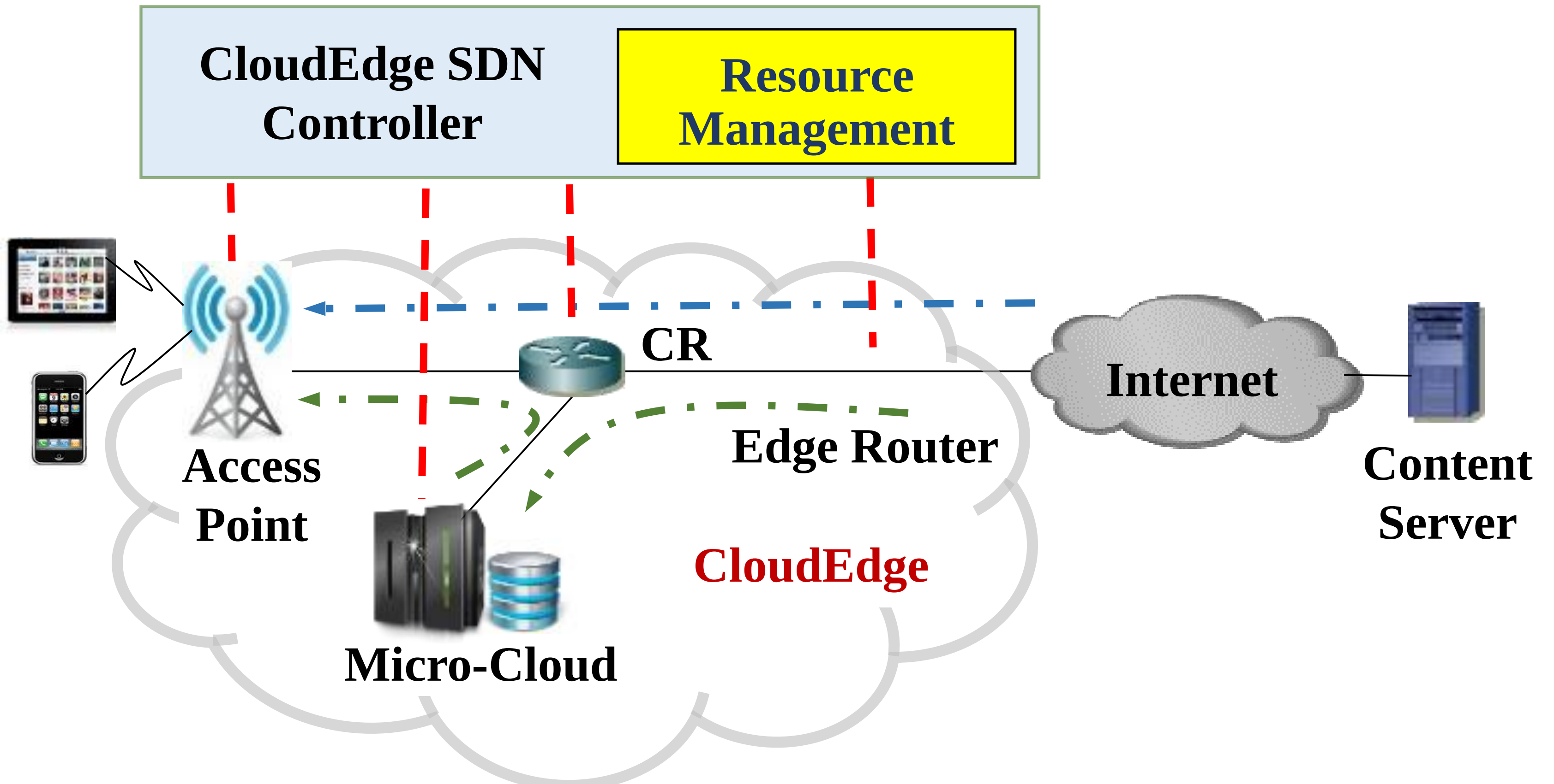
Objective Overview

CloudEdge, enables more efficient and robust content delivery, by utilizing SDN and Cloud technologies to give new capabilities to edge networks.

In this project we investigate one of the benefits of deploying an CloudEdge, specifically using it to optimize the average QoE for streaming video users of an Access Point.

The conjecture is that if an SDN controller could intelligently manage the data flows, a local video transcoder, and the access point utilization for each user, then it could optimize the average QoE of an access point.

CloudEdge System Architecture



CloudEdge SDN: Manages the Micro-Cloud and directs flows based on each AP user's SNR, the total number of users, and the bandwidth of the content requested in order to optimize the average eQoE of the AP.

Micro-Cloud: Provides resources for transcoding.

CUA

CloudEdge Operation

- Mobile users connect to an enhanced wireless access (AP) or cellular base station.
- The enhanced AP reports measured parameters including the AP data rate and bandwidth usage of each mobile user, to the CloudEdge controller.
- The controller calculates the parameters to optimize the QoE based on the input collected, this includes which users to drop, which to transcode, and the maximum AP channel time for each transmitted data flow.
- As part of the optimization the controller determines what flows require transcoding and directs them to the transcoder.
- Then the enhanced AP is configured with the optimized settings by the controller.

Mean Opinion Score (MOS)

The MOS was frequently used to measure QoE in traditional voice applications and more recently for VoIP as well as Video.

User Rating	MOS
Very satisfied	4.3-4.5
Satisfied	4.0-4.3
Some users satisfied	3.6-4.0
Many users dissatisfied	3.1-3.6
Nearly all users dissatisfied	2.6-3.1
Not recommended	1.0-2.6

User Ratings MOS As Defined in ITU-T Rec. G.107 Annex B

QoE Impact for Desired vs Received Resolution based on the ITU MOS Upper Limit

eQoE of Received vs. Desired Video Resolution					
Based on the MOS Upper Limit		Received			
		1080p	720p	480p	360p
Desired	1080p	4.50	4.31	3.98	3.55
	720p	-	4.50	4.31	3.98
	480p	-	-	4.50	4.31
	360p	-	-	-	4.50

Expected Quality of Experience (eQoE)

Calculating QoE is difficult, users request different qualities of content through different types of devices with different output and display capabilities.

QoE has become a quickly moving scale, what was considered great video quality a few years ago, is today, only second rate.

These facts led us to the concept of expected QoE (eQoE), which is the QoE score a user desires or expects based on a user's circumstances or limiting factors (e.g., network, device capabilities, content request).

The eQoE allows us to:

- Calculate the requirements for providing a specific desired level of QoE,
- Identify the most effective means of improving the QoE,
- Optimize QoE in support of network resource sharing,
- Compare the final QoE vs the eQoE.

Transcoding & Optimization Procedure

1. ***N*** **user's request video streams**

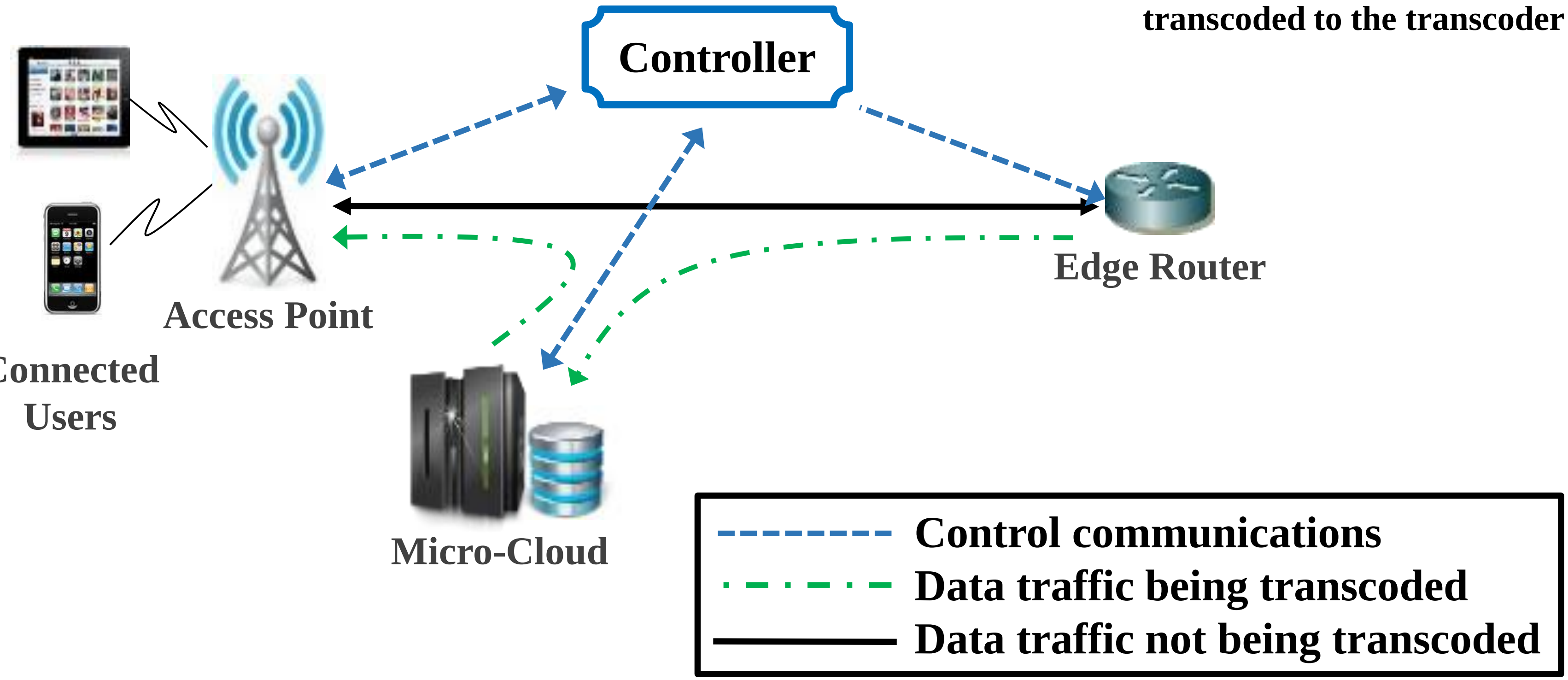
2a. Controller queries AP for each user's SNR

2b. Controller queries transcoder for available resources

3. Controller calculates settings to optimize the AP eQoE based on 1, 2a, & 2b

4a. Controller configures the AP utilization percentage for each user

4b. Controller redirects traffic to be transcoded to the transcoder



Baseline: eQoE with No Transcoding

The objective here is to establish a baseline for comparison by find the average eQoE for all video streams transmitted by the AP without CloudEdge Services.

When the combined throughput of all AP users exceeds the maximum AP data rate, the video data above the threshold is treated as the packet loss.

We calculated the highest potential eQoE based on percent packet loss as:

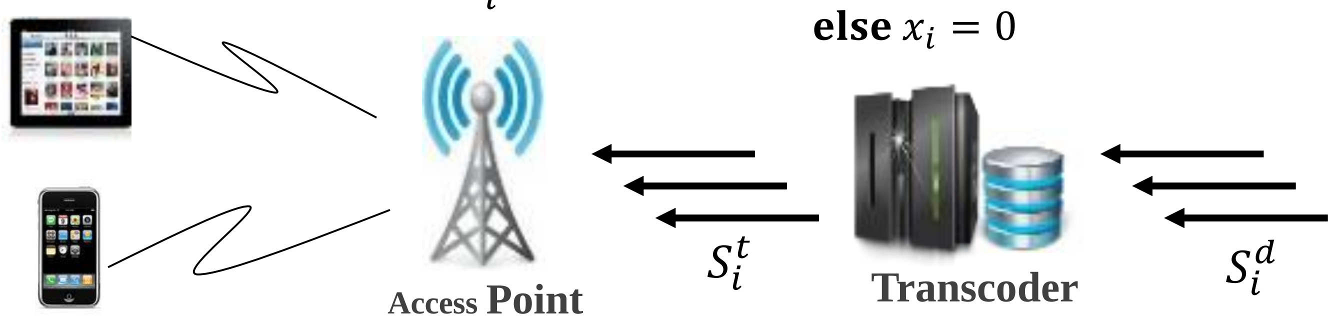
$$3.010 * e^{-4.473 * Packet\ Loss} + 1.49 \quad [2].$$

[2] Markus Fiedler, Tobias Hossfeld, Phuoc Tran-Gia, "A Generic Quantitative Relationship Between Quality of Experience and Quality of Service Network," IEEE Network, Vol. 24, No. 2., pp. 36-41, Mar. 2010.

Optimization eQoE with Transcoding

Equations, Variables, and Constraints:

$$Max \sum_i eQoE_i(\alpha_i, S_i^t)$$



$$\sum_{i=1}^{N} \alpha_i \leq 1$$

$$\sum_{i=1}^{N} c_i x_i \leq C$$

$S_i^t < S_i^d$ if $x_i = 1$ $(transcoding)$, **and** $S_i^t = S_i^d$ if $x_i = 0$ $(no\ transcoding)$

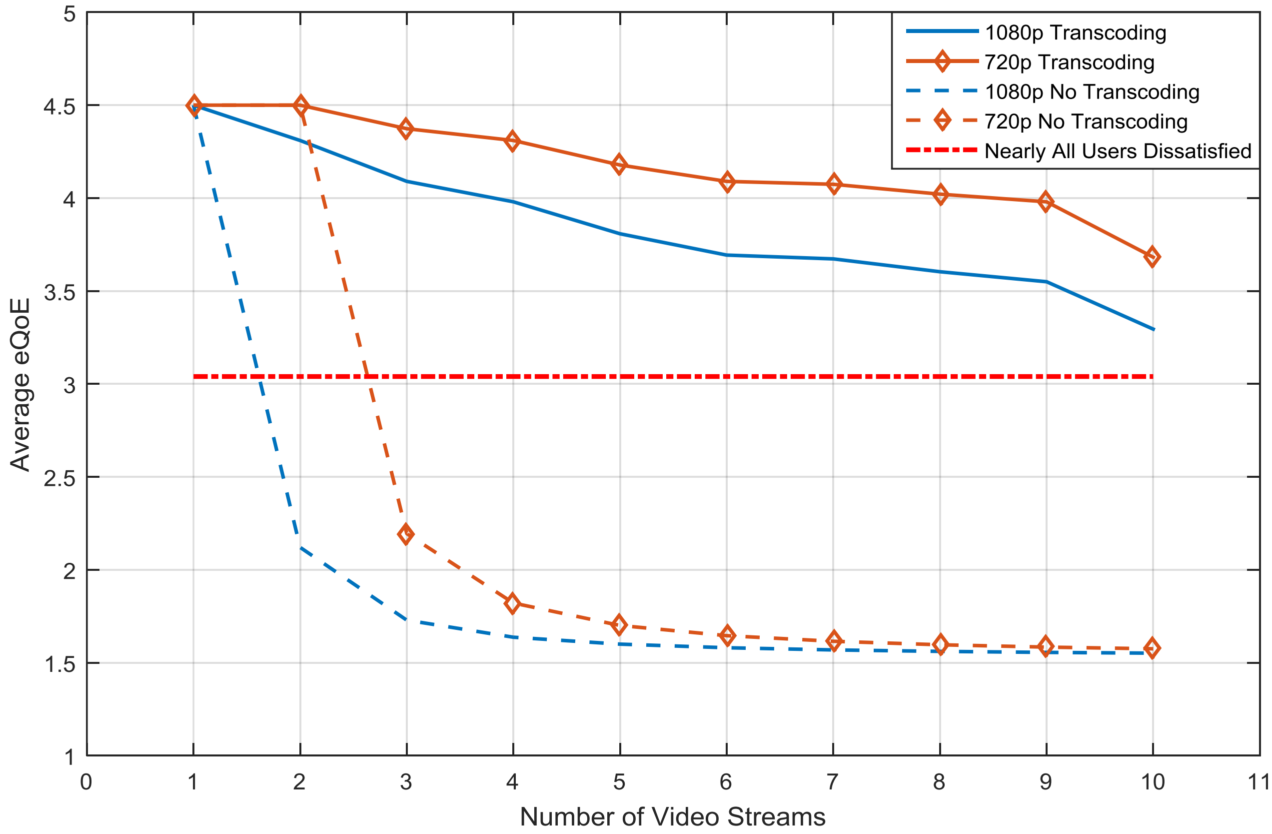
Total required bandwidth to transmit is $T_i = \alpha_i r_i = \delta S_i^t$, ($\delta$ = protocol overhead)

Results: eQoE w/ & w/o Transcoding

Based on the number of video streams requested, and the video resolution requested, we see the average eQoE in four different scenarios.

Two with all users requesting video at a resolution of 720p w/ & w/o transcoding

Two with all users requesting video at a resolution of 1080p w/ & w/o transcoding



Limited Transcoders Simulation

The next step after finding the potential benefits of having transcoding at the edge, was to take a preliminary look at the number of transcoders required significantly improve the average eQoE.

In order to clearly observe the impact of just transcoding, we ran two scenarios with the following fixed variables: 12 users requesting the same resolution and connecting at the same data rate.

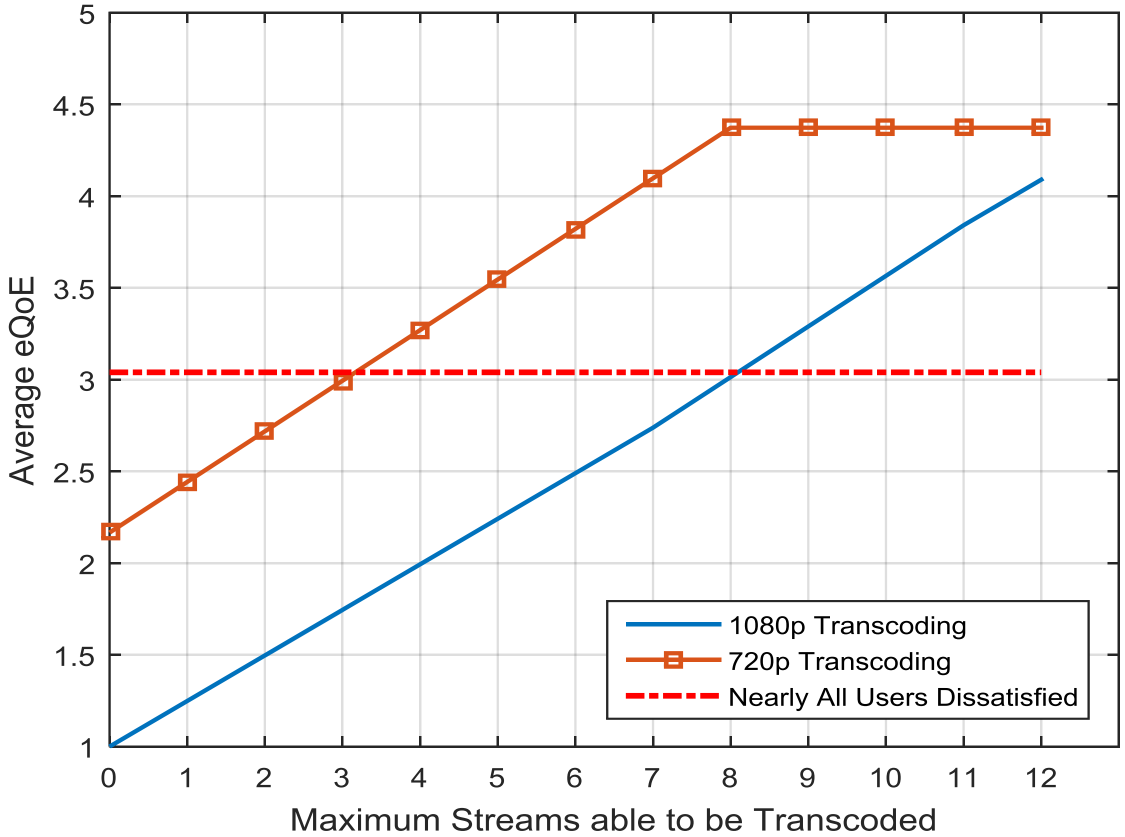
The graph starts with 0 streams able to be transcoded and ends at 12, the max useable number of transcoders ***C = N***

Results: Impact of Adding Transcoders

The impact of additional transcoders on the eQoE of a wireless edge network can be observed in the following two scenarios:

At 720p, 12 users require at least 7 transcoders to achieve a mean QoE of satisfactory

At 1080p, 12 users require a full 12 transcoders to achieve a mean QoE of satisfactory



Future Work

Our next steps include developing a more efficient and general algorithm to solve our multiple resource allocation optimization problem.

We are currently working on implementing this algorithm in a prototype CloudEdge network as a proof-of-concept to validate our results, and gather lessons learned to apply to our future research.

Additional optimization techniques being consider include:

- Finding the Max-Min eQoE
- Running an exhaustive search of the nonlinear discrete variables to find the theoretical maximum average eQoE of a scenario
- And optimizing the AP throughput

Thank you for your time,
are there any questions?

BACKUP

List of Variables & Equations

- A video stream i is sent to user i at a data rate of r_i
- The AP channel utilization is α_i
- The throughput of stream i is: $T_i = \alpha_i r_i$
- The data transmission must meet the wireless channel utilization constraint: $\sum_{i=1}^{N} \alpha_i \leq 1$
- The number of processing cycle needed to transcode a stream: c_i
- The total available processing cycles is: C
- x_i is used to indicate if a stream is transcoded $(x_i = 1)$ or not $(x_i = 0)$
- Then the transcoding constraint is: $\sum_{i=1}^{N} c_i x_i \leq C$
- The desired video rate is: S_i^d
- The final transmitted video rate (after transcoding if necessary) is: S_i^t
- The transcoder can only reduce the video resolution, i.e., decreasing the video rate. Therefore: $S_i^t < S_i^d \;\; if \;\; x_i = 1 \; (transcoding)$, and $S_i^t = S_i^d \;\; if \;\; x_i = 0 \; (no \; transcoding)$
- If δ denotes the protocol overhead, which includes the lower layer headers and overhead to transmit video data, then, the required bandwidth to transmit the video stream is

$$T_i = \alpha_i r_i = \delta S_i^t$$