Scalable Video Streaming over Multi-RAT Network

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***Abstract*— Efficient utilization of wireless resources is becoming more important with increasing data traffic being over wireless networks, especially multimedia traffic. Since the display panels in mobile devices are getting bigger and having a higher resolution, video streaming over a wireless network becomes a more challenging problem. Multiple Radio Access Technology (Multi-RAT) system is one of the solutions for streaming high-quality video through wireless channels since most mobile devices are equipped with multiple radio technologies, such as Wi-Fi and LTE. Moreover, scalable video is suitable to adaptively change the quality of the video depends on the wireless channel condition. In this research, optimal rate distribution through the Wi-Fi and the LTE will be derived to efficiently utilize both wireless technologies to transmit video to provide the best video quality to the user equipped with Wi-Fi and LTE.**

Keywords- Multi-RAT, SVC, integer programming.

I. INTRODUCTION

The Multi-RAT system can achieve a high data rate by using multiple data paths [1][2]. Long-Term Evolution (LTE) technology allows users to use both licensed and unlicensed spectrum to transmit data. When the licensed channels are congested because of a large number of users, LTE can off-load its data to an unlicensed spectrum. There are two ways to offload the data to an unlicensed spectrum. First, License Assisted Access (LAA) utilizes unlicensed spectrum by aggregate licensed spectrum and unlicensed spectrum. In this case, LTE users occupy a certain amount of unlicensed spectrum. Second, LTE can transmit its data over an unlicensed spectrum using Wi-Fi protocol. LTE users should fairly compete with Wi-Fi users in this case. We design our Multi-RAT system based on the second option because it fairly shares the unlicensed spectrum with Wi-Fi users. Figure 1 shows the overall system architecture transmitting Scalable Video Coded (SVC) video through Wi-Fi and Long-Term Evolution (LTE) channel [3]. First, the source video is coded, and it will be separated as multiple video layers which are composed of a single base layer and several enhancement layers. Second, depending on the channel quality, we will decide the number of layers to be transmitted. Third, the bit streams will be distributed to Wi-Fi and LTE channels to provide the best video quality to the user. Since the channel characteristics of Wi-Fi and LTE are different, the channel characteristics will be used to decide what portion of the data will be transmitted through the Wi-Fi and LTE, respectively.

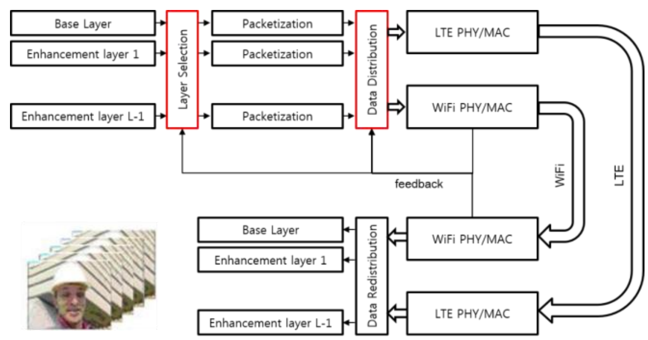

Figure. 1. The proposed SVC video streaming system.

The rest of the paper is structured as follows. In section II, we present a problem formulation. Section III presents a problem-solving strategy. Section IV presents simulation results and Section V concludes the paper.

II. PROBLEM FORMULATION

Peak Signal-to-Noise Ratio (PSNR) is the most popular way to measure the Quality of Experience (QoE) for video. However, in wireless communication settings, the receiver has no information about the original video and cannot measure the PSNR while still receiver also need to measure the QoE to adaptive rate control to efficiently utilize the wireless resource. Since SVC video has several data streams, receiver can estimate the QoE by counting the number of video layer successively received. For example, if the receiver has 4-video layers, then it will have better video quality than the receiver having 3-video layers. Therefore, this project focused to maximize the number of layers.

The optimization problem can be formulated as (1), which is maximizing utility function subject to the data rate constraint (2)~(5) of LTE and Wi-Fi channels. Defined utility is summation of all the layer's estimated utilities successfully received, where u is the QoE model from [4]. LTE and Wi-Fi have different PHY and MAC layer design, but both technologies are using OFDM as a fundamental data allocation. Therefore, we can estimate the throughput of each channel by using the number of sub-carriers allocated for the user in our interest.

$$\max_{r_{LTE}, r_{WiFi}} U(r_{LTE}, r_{WiFi}) = \sum_{l=0}^{L-1} u_l \, f_l(r_{LTE}, r_{WiFi}) \qquad (1)$$

subject to

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$$\sum_{l=0}^{L-1} r_{l,WiFi} \le (k_{WiFi}-k_{ov})\frac{B_{WiFi}}{k_{WiFi}T},\ \sum_{l=0}^{L-1} r_{l,LTE} \le \frac{B_{LTE}}{T}, \quad (2)$$

$$r_l \le r_{l,LTE} + r_{l,WiFi},\ \text{for } l = 0,\dots,L-1, \quad (3)$$

$$f_l(r_{LTE}, r_{WiFi}) = \prod_{k=0}^{l} corr_{LTE}\, corr_{WiFi}, \quad (4)$$

$$\begin{aligned} corr_{LTE} &= (1-P_e(\gamma_{LTE}, M_{LTE}))^{ceil\left(\frac{r_{k,LTE}T}{\log_2 M_{LTE}}\right)} \\ corr_{WiFi} &= (1-P_e(\gamma_{WiFi}, M_{WiFi}))^{ceil\left(\frac{r_{k,WiFi}T}{\log_2 M_{WiFi}}\right)}, \end{aligned} \quad (5)$$

u_l is the utility of l-th layer, L is the total number of video layers, T is symbol duration, $B_{LTE/WiFi}$ is the number of bits allocated to LTE and Wi-Fi channels, $\lambda_{LTE/WiFi}$ is received SNR of LTE and Wi-Fi, $M_{LTE/WiFi}$ is a modulation size of LTE and Wi-Fi, $k_{LTE/Wi\text{-}Fi}$ is the number of sub-channels in LTE and Wi-Fi spectrum, k_{ov} is the overhead for Wi-Fi channel to avoid collisions, $corr_{LTE/Wi\text{-}Fi}$ is the correction rate of LTE and Wi-Fi channels.

III. PROBLEM SOLVING

To solve the optimization problem, logarithm is taken to simplify the problem. Then, the problem turns out to be the integer linear programming problem. We can relax the problem to a general linear programming problem and rounding the result to get the integer results.

$$\begin{aligned} \bar{f}_l(N^k{}_{LTE}, N^k{}_{WiFi}) &= \log f_l(r_{LTE}, r_{WiFi}) \\ &= \sum_{k=0}^{l} \alpha_{LTE} N^k{}_{LTE} + \alpha_{WiFi} N^k{}_{WiFi} \end{aligned} \quad (6)$$

where,

$$\begin{aligned} & N^k_{LTE} = ceil\left(\frac{r_{k,LTE}T}{\log_2 M_{LTE}}\right), N^k_{WiFi} = ceil\left(\frac{r_{k,WiFi}T}{\log_2 M_{WiFi}}\right) \\ & \alpha_{LTE} = \log(1-P_e(\gamma_{LTE}, M_{LTE})) \\ & \alpha_{WiFi} = \log(1-P_e(\gamma_{WiFi}, M_{WiFi})) \end{aligned}, \quad (7)$$

A new problem statement is

$$\max_{N_{LTE}, N_{WiFi}} \bar{U}(N_{LTE}, N_{WiFi}) = \sum_{l=0}^{L-1} u_l\, f_l(N_{LTE}, N_{WiFi}) \quad (8)$$

subject to

$$\begin{aligned} & \sum_{l=0}^{L-1} N_{l,WiFi} \le \frac{k_{WiFi}-k_{ov}}{k_{WiFi}} N_{WiFi}, \sum_{l=0}^{L-1} N_{l,LTE} \le N_{LTE} \\ & r_l \le r_{l,LTE} + r_{l,WiFi},\ \text{for } l = 0,\dots,L-1 \end{aligned} \quad (9)$$

The problem is restated using standard form of the Linear Programming described as [5]

α	LTE (0.9)	WiFi (0.9)
Base	12	49
Layer1	7	26
Layer2	2	9
Layer3	5	18

(a) No overhead

α	LTE (0.9)	WiFi (0.9)
Base	15	46
Layer1	8	25
Layer2	3	8
Layer3	6	17

(b) $K_{ov} = 10$

α	LTE (0.8)	WiFi (0.9)
Base	1	60
Layer1	1	33
Layer2	1	10
Layer3	4	19

(c) $K_{ov} = 10$

Figure 2. Packet Distribution

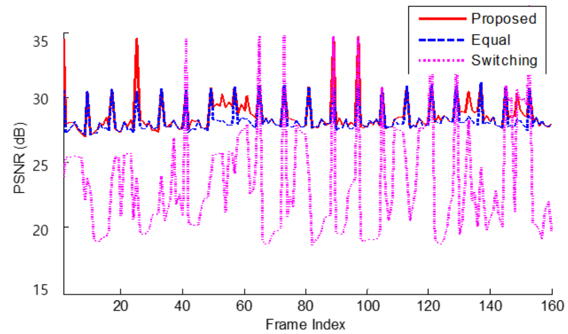

Figure 3. PSNR (dB) Performance

$$\begin{aligned} & \underset{x}{\text{maximize}}\ f^T x \\ & \text{subject to } Ax \le b,\ x \ge 0, \text{and } x \in Z^n \end{aligned} \quad (10)$$

where,

$$f^T = \left[\sum_{l=0}^{L-1} \alpha_{l,LTE} u_l \quad \sum_{l=0}^{L-1} \alpha_{l,WiFi} u_l \quad \dots \quad \alpha_{0,LTE} u_0 \quad \alpha_{0,WiFi} u_0\right] \quad (11)$$

$$x = \left[N^0_{LTE} \quad N^0_{LTE} \quad \dots \quad N^{L-1}_{LTE} \quad N^{L-1}_{LTE}\right]^T \quad (12)$$

$$A = \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 \end{bmatrix} \quad (13)$$

IV. SIMULATION RESULTS

Matlab and Joint Scalable Video Model (JSVM) software [6] were used to evaluate the proposed algorithm. Fig 2. shows the simulation results with different settings. We assume that the available number of resources are $N_{LTE} = 30$ and $N_{WiFi} = 120$. Fig 2(a). shows the packet distribution results with no overhead, where the overhead K_{ov} means required amount of resource to avoid collision in Wi-Fi network. Fig 2(b) shows the packet distribution when the overhead $K_{ov} = 10$, which is the case that Wi-Fi cannot fully utilize its resource to avoid congestion. Fig 2(c) shows the packet distribution when the channel condition of LTE is worse than the channel condition of Wi-Fi. The simulation results show that the proposed algorithm allocates more video packets to more reliable network.

For the comparison, equal data distribution and switching algorithm were also implemented. Equal data distribution only distributes the data to two channels with the same data rate. The switching algorithm selects the one channel which has better channel gain than other. Fig 3. shows that the proposed algorithm has the best PSNR.

V. CONCLUSION

Multi-RAT is a useful technology for streaming videos, since it can achieve better data rate than using only one channel at once. Moreover, if we distribute the data in an optimal way, the receiver will get better quality video. We proposed the optimal solution for data distribution between LTE and Wi-Fi and found that the proposed scheme can provide better quality video. The proposed algorithm will be expanded to 5G license assisted access (LAA) as a future work.

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