A Novel Software-Defined Networking Architecture for Future 5G Wireless Networks

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Abstract: **Virtual and/or Augmented reality (AR/VR) is the next-generation Internet and next-generation computing platform. AR/VR is publicly recognized as a virtual environment created by computers. The environment replicates a real world or creates an imaginary setting where users interact in real time with the virtual space. AR and VR require high energy and data rates. This scheme requires a higher bandwidth speed but a lower delay. To meet the AR/VR requirements a multipath cooperative route (MCR) scheme is proposed to overcome increasing traffic demands in future, to facilitate the AR/VR wireless transmissions in 5G small cell networks. A software-defined networking (SDN) architecture is designed. Furthermore, we have developed a service effective energy (SEE) optimization algorithm for AR/VR wireless transmission in 5G small cell networks. My Simulation results shows that both the delay and SEE of the proposed MCR scheme have better result. As AR\VR data require high energy consumption during transmission an SEEM algorithm is designed to minimize the energy consumption throughout network.**

***Index Terms*: Multimedia communications, cooperative communications, multi-path transmissions, network latency, energy consumption.**

I. INTRODUCTION

Nowadays computer graphics is used in many domains of our life. Augmented reality (AR) and virtual reality (VR) have the potential to be the next mainstream general computing platform [1]because of the increasing popularity and usage of different smart devices like smart phones, tablets, Google Glass, Apple Watch, etc., Augmented Reality (AR) is a new technology that involves the overlay of computer graphics on the real world. Virtual Reality (V.R) is a term used for computer generated 3D environment that allow the user to enter and interact with alternate realities. The users are able to "immerse" themselves to varying degrees in the computers artificial world. As the future 5G wireless networks could meet the 1000x traffic demands over the next decade, with additional spectrum availability, densification of small-cell deployments, and growth in backhaul infrastructures. There have been a great number of research activities to support the enormous traffic demands involved in AR/VR applications, in 5G network studies. The conventional single path route scheme has been proposed to overcome these problems of AR\VR data transmission but due to heavy traffic a multipath network is needed in AR\VR data transmission. To reduce the network latency and transmission delay in fiber optical networks in AR/VR various chromatic dispersion compensation methods were discussed. We have proposed a software-defined networking (SDN) architecture to reduce the network latency in future 5G wireless networks, a multi-path cooperative route (MCR) scheme for fast wire-less transmissions and a service effective energy (SEE) model proposed to evaluate the energy consumption of MCR scheme in AR/VR applications. Results show that delay and energy consumption of MCR scheme are better than the single path route scheme for AR/VR applications in 5G Small cell networks.

II. SYSTEM MODEL

A. Network Model

The reason to adopt SDN architecture is to support the separation of data and control information asin Fig. 1. In this model we have taken a two-tier heterogeneous cellular network, where multiple small cell base stations (SBSs) and EDCs are deployed within the coverage of a macro cell base station (MBS). The MBS and EDCs are connected to the core networks through fiber to the cell (FTTC).

In AR and VR transmission, first the user will send a request to MBS by uplink and then the MBS will search for EDC which is located closer to the user, if an EDC found outside the macro cell, through SDN controller associated MBS sends the request to the MBS to which this EDC belongs, after receiving the routing information transmitted from the MBS, the EDCs transmit AR/VR data to the destination SBS that is located closest to the requesting user. Finally, the destination SBS delivers the AR/VR data to the requesting user by mm Wave transmission links. In order to reduce the delay the content stored in EDC should be taken into account.

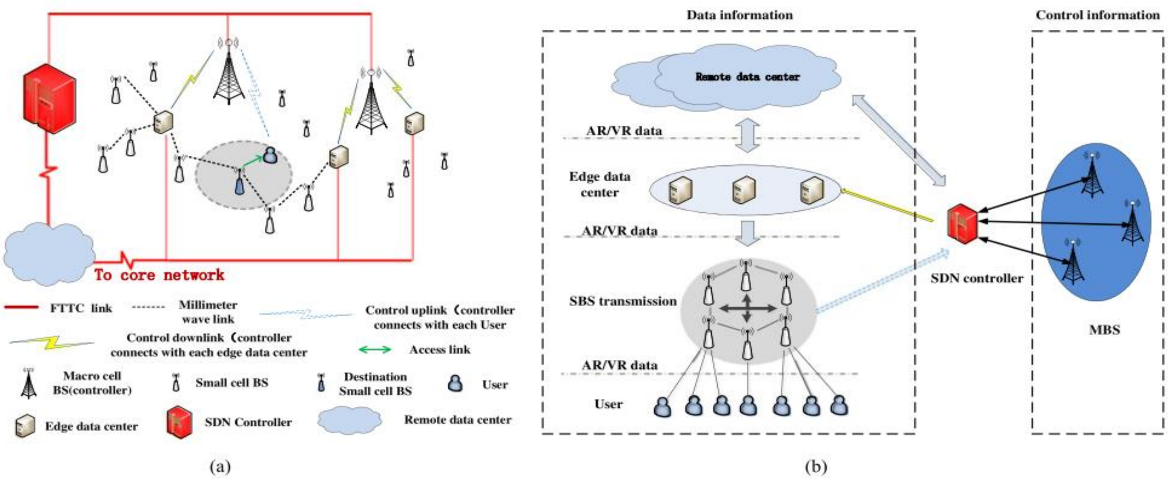

Fig. 1.SDN-based network architecture for 5G small cell networks. (a) Deployment scenario. (b) Logical architecture.

B. AR/VR Data Storage Strategies in EDC

To ensure acceptable performance of widely dispersed distributed services, large organization typically implement edge computing by deploying server farms with clustering and large scale storage networks. Edge applications significantly decrease the volumes of data that must be moved. EDC can store only a limited value of video contents, there are three strategies which are proposed in existing studies. First in first out (FIFO): The content at the head of the queue removed to put the newly incoming content at the tail of the queue. Least recently used (LRU): If the storage capacity of EDC is reached, then the least recently used content will be replaced by the newly incoming content. Popularity-priority: The more popular content are stored by comparing the popularity of the newly incoming content with that of the least popular content stored at EDC. The probability that an arbitrary user request is for AR/VR video content k. Without loss of generality

$$q_k = \frac{k^{\beta}}{\sum_{k=1}^{|k|} j^{\beta}} \qquad (1)$$

Where β is the skewness of the popularity distribution and is a positive value, The popularity-priority strategy is adopted in our considered network model, to store the most popular AR/VR video content data at each EDC. To maintain cache consistency, the popularity distribution of AR/VR video contents varies with time.

Network Latency Model In wireless networks, electromagnetic waves propagating through free space experience an attenuation or reduction in power density. This phenomenon is known as path loss and is caused by many factors which include absorption, diffraction, reflection, refraction, distance between transmitter and receiver. In AR\VR data transmission, after receiving the user's request, the delay in the network is formulated as

$$D_{UL}^{req} = (D_{UL}^{req,1} + D_{DL}^{deli} + D_{DL}^{bh} + D_{DL}^{as}).P_{in-EDC} + \left(D_{UL}^{req} + D_{DL}^{deli} + D_{DL}^{bh} + D_{DL}^{as} + D^{fiber}\right).(1 - P_{in-EDC}) = \left(D_{UL}^{req} + D_{DL}^{deli} + D_{DL}^{bh} + D_{DL}^{as} + D^{fiber}\right).(1 - P_{in-EDC}) \qquad \ldots\ldots. \ (2)$$

Where P_{in-EDC} is the probability that the user find the desired AR/VR data in the nearby EDC. The delays have been observed during the transmission of AR/VR data. D_{UL}^{req} is the delay occurred when a user terminal sends a request to the MBS through uplinks. D_{DL}^{deli} is the delay occurred while transmitting AR/VR data between MBS and EDCs through downlinks. D_{DL}^{bh} is the backhaul delay, i.e., the delay occurred while transmitting AR/VR data between EDC and the destination SBS which associates with the requesting user. D_{DL}^{as} is the delay occurred when the destination SBS sends the requested AR/VR data to the requesting user. D^{fiber} is the fiber delay incurred in the uplink/downlink transmissions when the MBS has to fetch AR/VR data from the RDC upon a search failure in local EDCs. To reduce these delays minimum transmission data has been considered.

The probability of successfully delivering the requested AR/VR data to the requesting user is expressed as

$$\rho_{DL}^{as} = P_r(\gamma_{DL}^{as} \geq \theta_3)$$
$$P_r(P_s r_u^{-\alpha 2} |H_{nu}|^2 \geq \theta_3)$$
$$\int_0^{\infty} \left(\sum_{t=o}^{n_s^r n_r^u - 1} \frac{2\pi\lambda sr}{t!} \left(\frac{\theta_3 n_t^s r^{\alpha 2}}{p_s} \right)^t e^{-\left(\frac{\theta_3 n_t^s r^{\alpha 2}}{P_s} + \pi\lambda s r^2 \right)} \right) dr \qquad (3)$$

Where $\theta 3$ denotes the received signal power threshold for a successful reception.

III. Multipath Cooperative Route (MCR) Scheme

Multipath Cooperative Communication is a technique which could be employed to mitigate the effects of channel fading by exploiting diversity gain achieved via cooperation between nodes and relays. To achieve transmit diversity, a node would generally require more than one transmitting antenna which is not too common due to the limits in size and complexity of wireless mobile devices. However by sharing antennas with other single-antenna nodes in a multi-user environment, a virtual multi-antenna array is formed and transmit-diversity is accomplished. Subsequently, radio coverage is extended without the need to implement multiple antennas on nodes and increased transmission reliability is achieved. Considering the fluctuation of wireless channels, it is very difficult to transmit the massive AR/VR data with the low system delay constraint by a fixed path in 5G small cell networks. On the other hand, the AR/VR data can be repeatedly stored in multiple EDCs according to the content popularity. Therefore, the same AR/VR data can be cooperatively transmitted to a user from adjacent EDCs. The basic multi-path cooperative route scheme is described as follows:

1) EDCs selection: selected EDCs transmit the AR/VR data to a destination SBS that is the closest to the requesting user and this destination SBS transmits the data to the user by mm Wave links.
2) Multi-path transmission strategy: Keeping the average distance between EDC and the destination SBS, EDCs are arranged incrementally. If the selected EDC away from the destination SBS the larger data is sent by nearby EDC and smaller data sent by distant EDC respectively.
3) Relay SBSs selection: To reduce the relay delay in SBS a relay route algorithm with minimum hop number is considered between EDC and SBS transmission path.

IV. Service effective energy optimization

A. Service Effective Energy

The AR/VR data transmission requires a high energy consumption to use energy efficiently throughout the network; the service effective energy (SEE) is defined by

$$E_{SEE} = E_{sys} Q_o S \qquad (4)$$

Where E_{sys} is the system energy of MCR scheme.

In AR/VR a computer generates sensory impressions that are been displayed in the real world. The type and the quality of these impressions determine the level of immersion. Ideally the high-resolution, high-quality and consistent over all the displays, information should be presented to all of the user's senses. Moreover, the environment itself should react realistically to the user's actions. As a consequence, the system energy of MCR scheme is extended as (30) where $E_{MBS}, E_{SBS}, E_{EDC}$ are the energy consumption at MBS, SBS and EDC, respectively; $E_{storege}$ is the energy consumption of one video content stored at the EDC; $P_{op}^{M}, P_{os}^{S}, P_{op}^{E}$ are the operation power of MBS, SBS and EDC, respectively; $T_{lifetime}^{M} T_{lifetime}^{E}\ T_{lifetime}^{S}\ e$ are the lifetime of MBS, SBS and EDC, respectively; $E_{EM}^{M}, E_{EM}^{S}, E_{EM}^{E}$ are the embodied energy of MBS, SBS and EDC, respectively; a_M, b_M are the fixed coefficient of operation power at SBSs; a_E, b_E are the fixed coefficients of operation power at EDCs.

$$E_{sys} = \lambda_M E_{MBS} + \lambda_S E_{SBS} + \lambda_E (E_{EDC} + \psi . E_{storage})$$

$$= \lambda(P_{op}^{M} T_{lifetime}^{M} + E_{EM}^{M}) + \lambda_s(P_{os}^{S} . T_{lifetime}^{S} + E_{EM}^{S}) + \lambda_E(P_{op}^{E} . T_{lifetime}^{E} + E_{EM}^{E}) + \lambda_E \psi . E_{storage}$$

$$= \lambda_M \left((a_M p_M + b_M) . T_{lifetime}^{M} + E_{EM}^{M}\right) + \lambda_s((a_S p_s + b_S) T_{lifetime}^{S} + E_{EM}^{S} + \lambda_E((a_E P_E + b_E) . T_{lifetime}^{E}\ E_{EM}^{E} + \lambda_E \psi . E_{storage} \qquad (5)$$

B. *Algorithm Design*

The energy should be efficiently used while transmitting AR\VR data as they consumes more energy. So, the optimal SEE problem is formulated by

$$\min\_(\lambda_E, \psi) E_{SEE} = E_{sys} Q_o S$$
$$S.I \sum_{k=1}^{\psi} x_{mk} = \psi, \forall, EDC_m \in \mathcal{M}$$
$$r_i \le R\_max$$
$$P_M > P_S > P_U \qquad (6)$$

Based on (6), the required system delay is formulated by

$$\max_{\lambda,\psi} Q_o S$$
$$S.I \sum_{k=1}^{\psi} x_{mk} = \psi, \forall, EDC_m \in \mathcal{M}$$
$$r_i \le R\_max \qquad (7)$$
$$P_M > P_S > P_U$$

Based on (2), the delays D_{DL}^{deli}, D_{UL}^{req}, D_{DL}^{as} are independent of density of EDC and the number of video contents. Therefore in this optimum algorithm the threshold delay of AR/VR is replaced by a variable.

$$D_{max} = D_{max} - D_{UL}^{req} - D_{DL}^{deli} - D_{DL}^{as}$$

The backhaul delay D_{DL}^{bh} decreases with the increase of the EDC density λ_E and the fiber link delay Df_l= D $_{fiber}$. (1- Pin-E DC) decreases with the increases in the number of video contents Ψ.

Step 2: Based on the result of Step 1, the minimum energy can be used by system in MCR is

$$\min_{\lambda_E, s} E_{sys}$$

$$\text{s.t.}\ (\psi, \lambda_E) \in \mathcal{C}(\psi, \lambda_E) \qquad (8)$$

where the available value pairs Ψ and λ_E^{ψ} are substituted into(5), the optimal SEE is solved by obtaining the minimum system energy of MCR scheme. The detailed SEE optimization (SEEM) algorithm is shown in Algorithm1.

Algorithm 1: Service Effective Energy optimization (SEEM) Algorithm

Input: D^{fiber} ,D_{max}, and relevant parameters about D_{DL}^{bh} ,$1 - P_{in-EDC}$

Output: The minimum value of E_{sys}, i.e., $E_{sys-min}$ the value pair vp_x , which denotes an available value pair (Ψ,λ_E(Ψ)) to get $E_{sys-min}$

Initialization: $i = 0$; $\Phi = \varphi$;

1) **for** Ψ = 1 : |*K*| **do**
   if $D^{fiber} \cdot (1 - P_{in-EDC}) > D_{max}$, **then**
   λ_E (Ψ) ← 0;
   else
   Compute equation D_{DL}^{bh}+ $D^{fiber} \cdot 1 - P_{in-EDC} = D_{max}$ with value Ψ to obtain the critical value λ_{cr} ;
   λ_E (Ψ) ← λ_{cr} ;
   end if
end for

2) **for** Ψ = 1 : |*K*| **do**
   if λ_E(Ψ) == 0 **then**
   Continue;
   else
   i ← *i* + 1; vp_i ← (Ψ, λ_E(Ψ)) ;
   Put vp_i into the set Φ;
   end if
end for

$$vp_x \leftarrow \min_{(vp_i \in \phi)E} E_{sys}(vp_i) ;$$

$$E_{sys,min} \leftarrow \min_{(vp_i \in \phi)E} E_{sys}(vp_i) ;$$

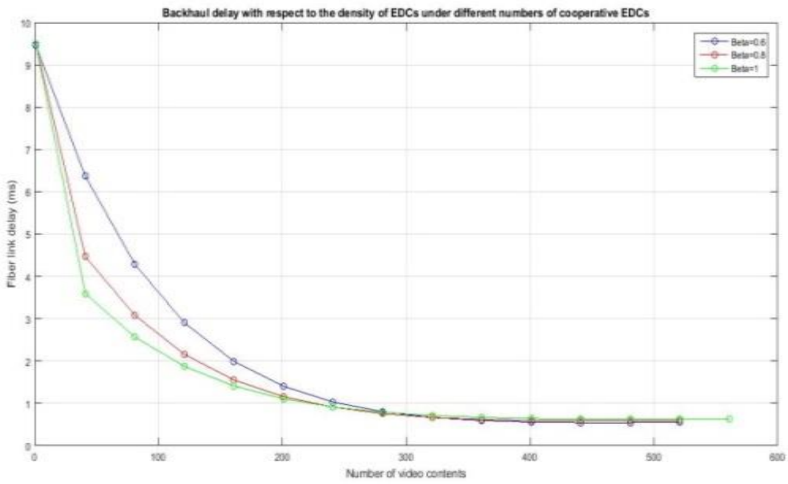

Fig. 2.Fiber link delay with respect to the number of video contents under different skewness parameters of popularity distributions.

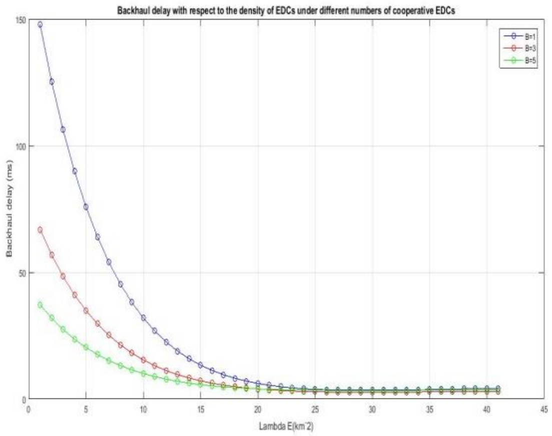

Fig. 3.Backhaul delay with respect to the density of EDCs under different numbers of cooperative EDCs.

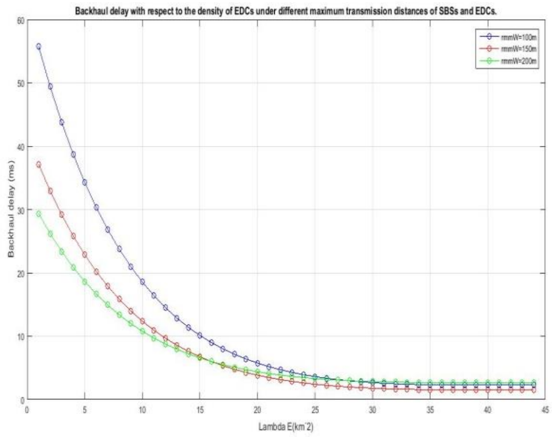

Fig. 4.Backhaul delay with respect to the density of EDCs under different maximum transmission distances of SBSs and EDCs.

V. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

The effect of various system parameters on the system delay of the MCR scheme is analyzed and compared by means of numerical simulations in this section.

In fig.2 we considered fiber link delay w.r.t number of video contents under different skewness parameter of popularity distribution. We can observe that the fiber link delay decreases with the increase of the number of video content at EDCs with the increase of the skewness parameter.

Fig. 3 illustrates the backhaul delay w.r.t the density of EDCs under different number of cooperative EDCs. Here the backhaul delay decreases with the increase of the density of EDCs

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Fig. 4 depicts the backhaul delay w.r.t the density of EDCs considering the distance between SBSs and EDCs. When the density of EDCs is fixed, the backhaul delay decreases with the increase of the maximum transmission distances of SBSs and EDCs

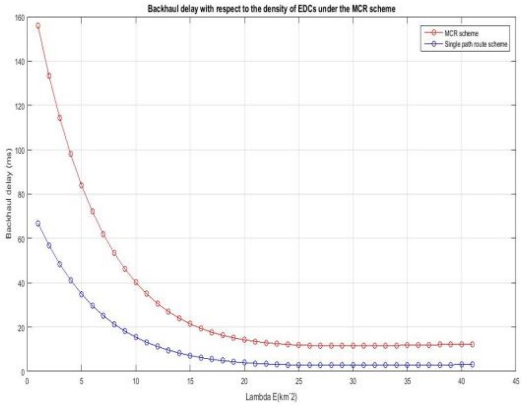

Fig. 5.Backhaul delay with respect to the density of EDCs under the MCR scheme and the single path route scheme.

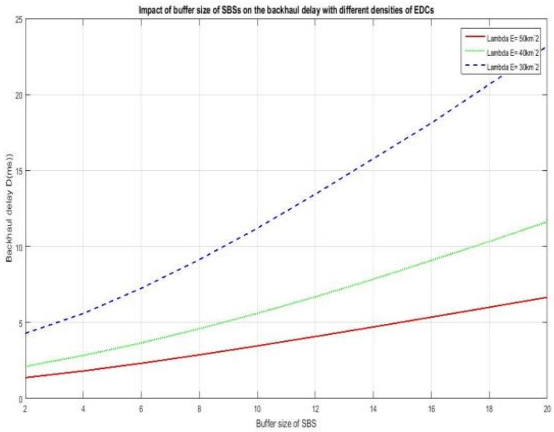

Fig. 7.Impact of buffer size of SBSs on the backhaul delay with different densities of EDCs.

The backhaul delay of MCR scheme is less than that of the single path route scheme. Fig. 5 shows the backhaul delay w.r.t the density of EDCs under the MCR scheme and the single path route scheme. Fig. 6 indicates the gains in terms of backhaul delay decrease with the increase of the density of EDCs. Fig. 7 depicts the impact of buffer size of SBSs on the backhaul delay with different densities of EDCs is investigated. When the density of EDCs is fixed, the backhaul delay increases with the increase of the buffer size of SBSs. Fig. 8 presents the backhaul delay with respect to the density of SBSs under different maximum distances between the EDC and the destination SBS. When the density of SBSs is fixed, the backhaul delay decreases with the increase of the maximum distance between the EDC and the destination SBS. Fig. 9 presents the system energy with respect to the density of EDCs under different numbers of video contents stored at EDCs. When the number of video contents is fixed, the system energy increases with the density of EDCs.

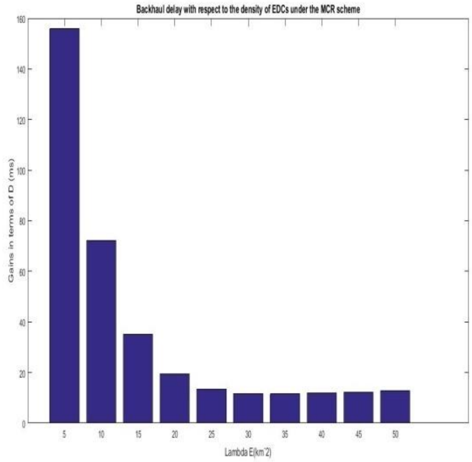

Fig. 6. Backhaul delay with respect to the density of EDCs in terms of gain

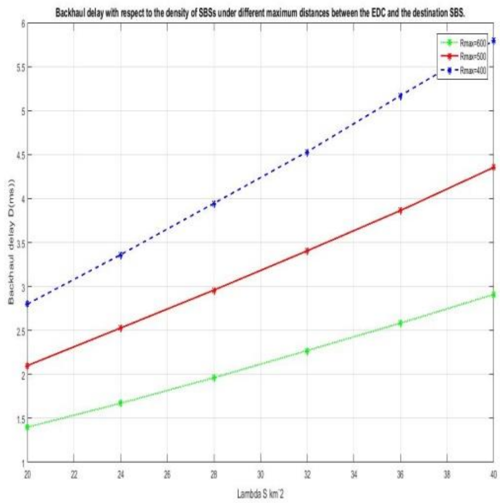

Fig. 8. Backhaul delay with respect to the density of SBSs under differentmaximum distances between the EDC and the destination SBS.

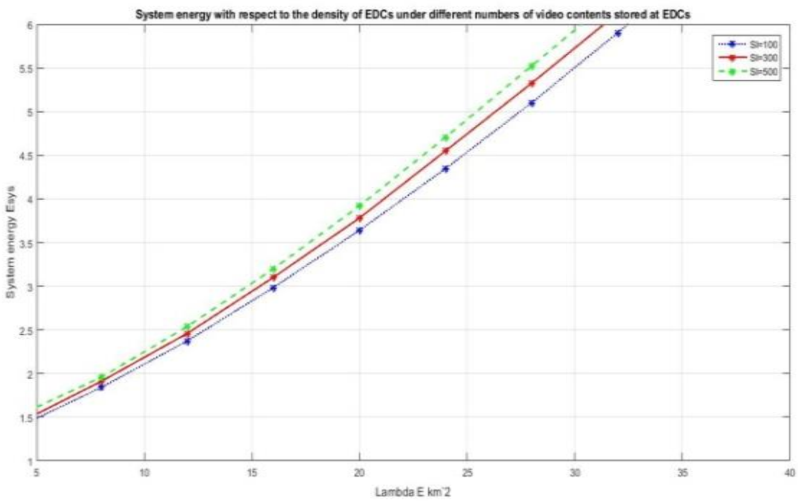

Fig. 9. System energy with respect to the density of EDCs under differentnumbers of video contents stored at EDCs.

VI. CONCLUSION

The transmission of AR\VR data requires lower latency and limited energy consumption. In this paper a software defined architecture (SDN) is proposed to reduce latency during transmission of AR\VR data and for massive data transmission, due to the presence of heavy traffic in future 5G small cell networks a MCR scheme is proposed. As AR\VR data require high energy consumption during transmission an SEEM algorithm is designed to minimize the energy consumption throughout network. Simulation results indicate the reduction of delay with respect to different parameters and also compare the conventional single path route to the MCR showing that MCR scheme is more efficient than single path routing scheme.

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