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Video Application on Ultra-Dense Network

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Abstract

The exponential growth and availability of data is the main driving force to the continuing evolution in the communication industry. The mobile video traffic is the main component of the immense amount of traffic generated by smart devices and requires a paradigm shift in all aspects of mobile network. Ultra-dense network (UDN) is one of the leading ideas where the access nodes and the communication links per unit area are densified. In this paper, we provide an introduction of UDN and video services. The relative techniques are summarized as well as the recent finding. Finally, we discuss the problems to the researchers in the field of video application in UDN.

Keywords: Ultra-dense network; Mobile data traffic; Scalable video coding; Luby transmission codes

1. Introduction

According to the global mobile data traffic report of the newest Cisco Visual Networking Index, the global mobile data traffic was 400 petabytes per month in 2011, and it had reached 7.2 exabytes per month at the end of 2016, while it is forecasted to reach 49.0 exabytes per month by 2021. Which means that, the mobile data traffic had grown 18-fold from the past five years, and will increase 7-fold in the next five years[1]. With the increasing popularity of smart devices, user-oriented mobile multimedia services, such as e-healthcare, video conference, video surveillance, and online gaming, especially for the high resolution (HD) video and ultra-high resolution (UHD) video with high quality requirement are rising rapidly, which led directly to the mobile data traffic provided by smart devices for a dominant position. As of the end of 2016, smart devices accounted for 46 percent of the total mobile

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devices and the 89 percent of the mobile data traffic was generated by these smart devices. The report also predicts that the total number of smart phones will be over half of the global devices and these smart phones will provide 86 percent of the mobile data traffic by 2021. That is to say, nearly 90 percent of the total mobile data traffic of one year is now available from the smart phones and will last to 2021 at least.

The mobile video traffic was accounted for 60 percent of all the global mobile data traffic, and it will be 78 percent by 2021. The mobile video traffic has becoming a dominant traffic in the global mobile data traffic today[2]. Thanks to the technology development in the fields of smart devices and radio access network, users of smart devices could enjoy the high resolution video services for working or entertainment. For example, video sharing, video conference, and online video platform (e.g. YouTube) all provide high quality video streaming to improve the user experience. And in the future, new advanced video services, like three dimensional (3D) hologram and virtual and augmented reality, are on the way.

Video traffic has its own characteristics compared with other traffic. First, high quality video means high spatial and temporal resolution video, which needs high data rate and high transmission bandwidth. The HD video needs 10Mb/s bandwidth while the 4K UHD video (3840×2160) and 8K UHD video (7680×4320) consume 60 Mb/s and 240 Mb/s, respectively. Secondly, the video data is encoded and organized by group of pictures (GOP). One GOP contains one intra coded frame (I frame) and several predicted frames (P frame) or bidirectional frames (B frame). I frame is encoded independently and could be decoded by itself, simultaneously, it has provided reference resource to the P frame and B frame during the decoding process. P frame is encoded based on the motion information of the original frame corresponding to itself and the original frame corresponding to the previous encoded frame; and P frame would be decoded via itself and the decoded previous frame. The coding and decoding process of B frame is similar as that of P frame, while the difference is that using the adjacent original frames to obtain the motion information in the coding process and utilize it in the decoding process[3].

The special characteristics of video traffic require particular treatment in order to offer high quality video and high user experience across the heterogeneous networks. The fifth generation (5G) mobile communication technologies are expected to appear on the market and achieve the particular treatment to supply the high quality of video services in the background of growth of data volume in the mobile network and the growth of wireless devices and variety of provided services. It is prospective that the 5G mobile communication technologies will offer about 10 Gb/s to 100 Gb/s data transmission rate. The customers' experience quality will be guaranteed under the 5G networks in the near future[4].

Considering the storage space, transmission bandwidth and fault tolerance, the network close to the clients would offer buffered video and deliver with less traffic load and less network latency by the network edge (i.e., base station or end-user devices)[5]. The concept of ultra-dense network (UDN) or the hyper dense heterogeneous and small cell networks (HetSNets) has represented a new paradigm shift in the 5G networks which improves the network capacity. The basic idea of UDN is to get the access nodes as close as possible to the clients. The realization of the hyper density is to deploy small cells densely in the hotspots generated massive traffic. Hence, the deployment of ultra-dense small cells has played a key role of the promising approach. These small cells are access nodes with small transmission power and small coverage which are deployed in or beside the customers' house (such as on the trees, walls or lampposts) or the hotspots (e.g. super market, train station or airports). Through the above UDN deployment scenarios, a different coverage environment that users would be as close as possible to many small cells has coming. Because the distance between users and access nodes is shorter, the link quality is also be improved[6].

Although the mobile video traffic is close to tow thirds of the total global mobile data traffic, there is only few researches researching the mobile video under UDN. In this survey, the overview of UDN and relevant technologies about video are introduced in the following section; then we review the recent technologies using in mobile video traffic under UDN; the challenge and open problems are discussed in the penultimate section. We conclude and summary this survey in the last section.

2. Background and Related Technologies

In this section, we first provide a basic background of UDN for better understanding, then H.264 scalable video coding (SVC)[3], as well as the Luby transform (LT)[7] codes, which are considered and integrated over UDN are briefly described in the following.

2.1. Ultra-Dense Network

UDN creation with heterogeneous cells arrangement and radius of less than 50 meters is one of the 5G network technologies development goals. So, what is the UDN? Ultra-dense networks can be defined as the networks where the number of small cells is more than client number. That is to say, the clients are close enough to the access nodes. The quantitative density at which a network can be considered as ultra-dense network is more than 1000 small cells per square kilometre[8]; and in the dense urban scenarios, the active users density is upper bounded by about 600 users per square kilometre[9]. The small cells could be deployed indoors in buildings and outdoors on the trees, lampposts, and building walls. The small cell and the macro cells are presented at the same time in the spectrum.

The small cell under UDN domain can be divided into two categories, namely base station and extension access points. The role of base station in UDN, like the traditional one, is the fully function base station, however, with small coverage range. There are two sub categories in UDN base station, which is Picocell and Femtocell. Picocell is the base station which is deployed at outdoor with the coverage of hundred meters by carrier service provider. However, the Femtocell is usually installed indoor environment like shopping mall, gymnasium, other public place or private areas. The goal of the deployment of Femtocell is to serve a small group of customers with a lower transmission power and higher installation density. The Femtocell works in three modes: open, closed and hybrid. The extension access points are the extension of the UDN, which is commonly used to cover the dead zone of the base station or replay the network.

Besides the feature in traditional networks, new features spring up in UDN. The UDN makes discrepancies compared with traditional networks, which resulted from different deployment method and network topology. The highlighted differences among them are explained as follows.

First, the cells are closer to the end user. The cells in UDN are smaller than the traditional one with lower footprint and lower power consumption. Because of closer distance between the end terminal and the source, the lower transmission delay can be reached to improve the fluidity of real-time application on the top of the link.

Second, the interference problem among small cells in UDN become extremely prominent because of the higher density of cells. Therefore, a feasible algorithm must be proposed to lower or reduce the same frequency interference between the small base stations.

Third, backhauling become one of the new challenge faced by the carrier service provider with the growth of the number of the small cells. The high network throughput and low time delay between backend server and frontend cells should be considered in the UDN. According to a famous Cannikin Law, the shortest barrel wood will determine the amount of water, so this challenge should be resolved, or it would limit the capacity of the UDN.

At last, with the help of flexibility of the small cells, the density of cells not only exist in horizontal direction but also present on vertical dimension. The distribution of the craft in building is not uniform, hence, the deployment of the small cells might be different either in horizontal and vertical. So that different modelling would be needed for these two dimension which is different from traditional operation network.

2.2. Video Application in UDN

The 5G network fits the rapid growth of demand of mobile data traffic and provides the robust communication infrastructure for the data intense application like video application. The year of 2016 is called the first year of the mobile live video streaming, or mobile broadcast, with the development of social interaction method. The need of mobile video streaming like application is the explosive development. In the future, more and more people would participant into the mobile live. New network paradigms emerged in 5G UDN, hence, new application pattern will be created based on these new feature.

The peer to peer (P2P) communication is mature and ubiquitous in traditional wired connected network, however, in mobile network domain, a lot of work is needed to be done. The P2P communication has two sub categories, device to device directly and network assisted P2P network. In first scenario, two peers can create a point to point network without the help of other network device, like a tunnel, via self-negotiation. The video application like screen sharing can be classified into this category, the encoded video package is transmitted from one device to another one without intervention of other router device. Without the package routing delay, a fluidity interaction experience can be achieved to user. The second scenario is complicated in many perspective. For the high data transmission efficiency, an optimal peer discovery algorithm should be further delved on the base of the current process. Meanwhile, the mobile device is usually powered by the limited capacity battery, hence, the power consumption allocation method should be taken into consideration.

The user association algorithm is critical for the operation of the UDN. In the UDN scenario, the end terminal has many candidate cell to be associated with. Hence, which one is the best choice at that timestamp should be considerably thought. In the video on demand (VoD) application, the distance between small cell base station and video server is different with each other. So when the user want to view a video stream file, an optimal route path should be chosen to achieve lower transmission delay and package routing delay.

In some case, the end terminal can associate with more than one small cell. For the high definition video application, huge amount of video data should be downloaded from the remote server to client application. Meanwhile, the current VoD application server architecture is constructed with a CDN server, which means that a same data will be stored with multiple copies on different server. Such that, in the multi-association case, an optimal strategy can be employed to selectively download video files from different server parallel in order to improve the throughput of the network.

2.3. Overview of video services

The main video services close to the customers could be divided into two categories. One is real-time video services; the popular applications could include video conference, video chatting, and video surveillance and so on. This kind of video services should encode the video data at one side firstly, then transfer through the network, and finally decode the received data at the other side. For example, for the service of video chatting, two or even more than two persons chatting via Facetime, QQ video call, Wechat video call or others, each client has two major works working concurrently, namely encoding the local live video then transferring and decoding the received video traffic. The process of encoding and transmission has its own encoding rule and transmission rule, and the network condition may not stable, all these would contribute to the latency and quality reduction. Even the network condition is good enough for the video service, we still feel a little latency compared with talking face to face.

The other category of video service is non real-time video. The most typical service is VoD. No matter which client we use, what we want to view is already encoded and exist at the server. Generally speaking, the process of VoD service is that, the client sends a video request to the server, the server receives the request and allocates the video data to transfer, and then the client receives and decodes the transferred data packet and plays on the player. When we send a video request via VoD platform, the platform will select the resolution level according to the network condition. There exist buffer time after we send the request and before the video playing. The buffer time may be long when the request video is not popular or the network condition is bad; on the contrary, it may short when the request video is popular or the network condition is good. For instance, for an extreme situation, we create a private cloud in our home using one laptop as the server, and save several video files in it; when we want to view one video in the private cloud, the request sends out and the video starts playing almost immediately. The butter time is almost nonexistent. The normal situation is that, after the butter time of few seconds, the requested video begins playing. However, the network quality may drop during the playing process, if we do not choose a lower level of resolution, the playing process would be interrupted and the video would be pause because there is not enough video data packet to decode and play. This period would last until the client receives enough data packet to continue playing.

Considering the two main categories of video services, researches on real-time video and popular videos have been studied and the details is shown in the next section.

2.4. Scalable video coding

Nowadays, the video applications are not limited to indoor network environment. Thanks to the rapid development of mobile communication technologies and the reduced price of mobile traffic, customers could enjoy the video services outdoors. Under the heterogeneous networks, the requirement of videos and the link conditions are different between each client. The H.264 scalable video coding (SVC) is considered and integrated to provide reliable, feasible and scalable video services.

The scalable video coding standard[3] is an extension of the well-known H.264/AVC standard. The scalability is reflected on the spatial, the temporal and the quality. The spatial scalability means for the same video, different resolution frames (e.g. 720p and 1080p) would be obtained at the same time. The temporal scalability means the adjustability of frames per second. The scalability of quality means the frame quality could be graded. Hence, this standard provides a coding scheme of bit streams with multilayer, one base layer and several enhancement layers. This kind of scheme is adaptive to various client devices in error-prone heterogeneous networks. In other words, a client may receive more coded data packet under better network environment than that under worse network environment; and the receiving client is allowed to receive incomplete data packets and the SVC decoder is still working with some level of quality degradation.

2.5. Luby Transmission Codes

Like the description[10], one video is firstly partitioned into several data blocks, then the data blocks are organized into different classed based on the scalability layer that they belong to and distribute to network coding nodes. The network coding node is responsible for receiving, encoding and transferring operations. The SVC is selected as the coding standard of video source. Besides, when transmitting video data in error-prone networks, applying channel coding as data protection, the multilayer property of SVC is adopted as well. The rateless channel coding is considered as well as SVC to provide reliable and scalable video service in UDN, and the fountain codes is selected to realize it.

The concept of fountain code is first proposed by John Byers and Michael Luby in 1998, it is an ideal solution for large-scale data distribution and reliable broadcast. The famous reason of fountain codes is that it allows to transfer files under a lossy connection, and the transmission process does not rely on the packet loss rate while the receiver side does not feedback which data packet is lost. When the transmission is under channels with erasures, it depends on the continuous and dual direction communication of the sender and the receiver. The transferring, feedback and retransferring operations are maintained until all the data packet are transferred and decoded successfully. Fountain code is a class of rateless code. For rateless code, the sender side does not need to set the fixed rate, and on the contrary, the sender side could generate limitless number of encoded packet. When the receiver side receives the data packet, it begins trying to decode. If the decoding is failed, the receiver continues receiving data packet and tries decoding again until the decoding is successful. Once the decoding successes, the receiver side sends a simple feedback signal to the sender, and the whole transmission is over.

The basic idea of fountain code could conclude as receiver can successfully recover K original source symbols with high probability when it receives enough (little larger than K) encoded packets which generated from a given set of source symbols by the senders. The biggest feature of this kind code is regardless of the statistics of the erasure events on the channel, sender can send as many encoded packets as are needed in order for the decoder to recover the source data. Luby Transmission codes (LT codes)[7] are the first realization of fountain codes. With the researching field of LT codes is becoming bigger and bigger, LT codes are especially suit for the broadcast and multicast service in the mobile communication. The application of LT codes could summarize as three aspects. At first, LT codes could transfer large file with high speed under wide area network, the Internet, and satellite network. LT codes aim at protecting the large file and realize via software, which could offer an approximate to the network bandwidth for large file transmission under radio access network, mobile network, Internet and satellite network. Secondly, LT codes provide quality improvement of VoD or broadcast of streaming media. LT codes are good channel coding method of streaming video, audio, video games or MP3 files. Thirdly, LT codes supply reliable data broadcast without channel feedback under mobile network, Digital television broadcasting network, telecommunications network and satellite broadcasting system. Without channel feedback, the increase of user number has no influence on the sender, namely, the sender could serve any number of users. The detailed of fountain code and LT codes is given[7, 11].

With the explosive growth of wireless multimedia applications over the wireless Internet in recent years, when fountain code is utilized in big scale multimedia transmission, the traditional LT codes is no longer satisfied the unequal error protection (UEP) of real-time multicast services. A novel approach to provide UEP using rateless codes over channels with erasures, named Expanding Window Fountain (EWF) codes, is developed[12]. EWF codes use a windowing technique rather than a weighted (non-uniform) selection of input symbols to achieve UEP property.

3. Recent Achievements

In this survey, we mainly summarize the video related under the UDN environments. Due to the above description, video services has two major services, namely real-time video and non real-time video. Two literatures[2,5] contribute to these two kinds of services.

Đào et al. proposed a solution to handle real-time video traffic in the software defined radio access networks[2]. The current solution of real-time video streaming may be not available under UDN environment. Since the radio nodes in UDN is more than active users, in other words, the number of served active user by one radio node is small, the peak-to-mean (P2M) rate radio would still cause short time congestion in the radio node. Meanwhile, the high P2M radio of video would make negative impact to the best-effort traffic in today networks. First, the dynamic effective rate of video flows is estimated via online method. The video player of user devices could report quality of service (QoS) and quality of experience (QoE). According the mapping function between the feedback value of QoS and QoE, the effective rate is calculated and changing with time. The paper used software defined networks technologies to handle the best effort flows and the constant bit rate in UDN and utilized fountain code as the channel coding mode to support mobile video user. The simulations are realized under the UDN, and the result showed that the solution gave a higher network capacity as well as better user QoE.

Yen et al. provided a distributed delivery method for streaming hot videos over ultra-dense wireless network environments[5]. The channel coding of LT codes and the source coding of SVC are deployed on the hot video clip. The encoded data packet are randomly distributed among the UDN nodes (small cells or attached servers). The benefits of random distribution also gave here. During the decoding process, the participating nodes can be randomly selected instead of the specified nodes. The source data can be recovered with high probability when multiple nodes failed. The surviving nodes can repair the failed node via regenerating the encoded data. The paper applied two random allocation schemes to balance the storage space, transmission bandwidth and fault tolerance requirements. The basic idea of allocation is that giving different weight to different layers. The SVC scheme is multiple layers scheme with one base layer and several enhancement layers. The allocated weight of base layer is the highest than that of other enhancement layers. The simulation of distributed delivery was realized under the UDN, and the result is that each request can be served with an acceptable quality at least, when the loss rate is less than 10%, an enhancement layer could be received in average.

4. Open Problems

While the UDN creates many opportunities, there are also some challenges and problems at same time. In this section, the facing problem is studied for future further research to pave the road of successful deployment of 5G UDN. The challenge is listed as follows.

In UDN, one obvious feature it required is flexible and agile, the topology and the route table should be dynamically update on the fly, such that, the software defined network will be the best candidate solution for this requirement. So the method of combination of UDN and software defined network should be further delved in future. The software defined network needs more operation technology in daily works.

The user association has been vastly researched on traditional network, however, new problem raised in UDN, for instance, in multiple association case, the metrics is needed to be defined for the optimal route path. The metric should be customized for different video application scenario, like real-time stream video and VoD application.

The delivery of high quality video to multiple viewers accessing the content from various devices and networks with various conditions is a challenging task. Transferring the same content (often with large volume) to multiple viewers drives unicast transmission inefficiently. Multicast transmission is a good choice to transfer the same content to multiple viewers. Furthermore, traditional multicasting is not an optimal solution for heterogeneous networks. Hence, new delivery solutions with the goal of reducing the output rate of the source and tailored to heterogeneous networks is necessary.

Our team is studying multicast based on software defined network in recent years, such as network coded group multicast routing problem, minimizing the maximum link utilization in multicast multi-commodity flow networks, two-level decomposition for multi-commodity multicast traffic engineering, also the QoE and QoS problem are considered. In particular, for 5G UDN, our team also study a video multicast orchestration scheme, named hybrid and concurrent multicast (HCM)[13]. The HCM identifies users requiring the same video content at different moments and then orchestrates a multicast-based content distribution scheme for users, which distribute video content based on unicast communication in UDN and is useful for avoiding the heavy consumption of spectrum resources. The video users in HCM can obtain non-live video content concurrently via multiple coexisting multicast trees. This HCM may provide some ideas to the above challenges.

5. Conclusions

In this paper, we provided a general overview of the video application on UDN and the challenge and opportunity came with the next generation communication network. The development of UDN network is rapid with the catalysis of the demand of data intensive video application on mobile data. The UDN is suite for the high network throughput application and can provide potential capacity redundancy for future data intensive application. This article presents the new paradigm of video application with the help of the new feature of the UDN; P2P communication and multiple user association. Meanwhile, the article also studies the channel encoding and source encoding schema in the case of UDN.

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