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TABLE V: Summary of works on video analytics in edge-C3.

Class	Ref.	Contribution(s)	Algorithms for analytics	Local	Edge	Cloud
Surveillance	[162]	Optimization problem for offloading and scheduling neural network layers to edge servers	AlexNet, CNNs	×	✓	✓
	[142]	Decision framework for energy-efficient offloading of analytics tasks; energy-aware edge routing algorithm	CNN (ResNet)	×	✓	✓
	[144]	Network architecture for cognitive radio and edge-assisted analytics; spectrum-aware placement of services at edge servers	-	×	✓	✓
	[170]	Framework for video analytics on cameras including controller that dynamically re-configures QoS parameters	HOG, Haar cascade	✓	✓	×
	[164]	Query optimizer that determines optimal placement and configuration of parameters for analytics tasks	CNNs	✓	✓	✓
	[165]	Platform for collaborative analytics; optimization problem for offloading tasks that minimizes response time	OpenALPR	×	✓	✓
	[163]	Query optimizer that determines optimal placement and configuration of parameters for tasks in analytics pipeline	OpenALPR, CNN	×	×	✓
	[166]	Platform for cooperative processing of videos on smartphones	AlexNet	✓	×	✓
	[168]	Cooperative video processing on smartphones; optimal forming of UE clusters and dispatching video chunks to the clusters	-	×	✓	×
	[169]	Video surveillance system at the edge; selecting frames such that number of frames with objects of interest is maximized	Haar cascade classifier	×	✓	✓
Augmented Reality	[171]	Optimization problem to minimize the energy required for offloading tasks from analytics pipeline to edge servers	-	✓	✓	×
	[146]	System for object detection that can run at high frame rates	R-CNNs	✓	✓	×
	[172]	System for continuous vision on smartphones; analytics pipeline for faster processing	CNNs, Viola-Jones detector [152]	✓	✓	×
	[174]	Multi-objective optimization problem for task assignment and frame resolution selection	YOLO	×	✓	✓
	[173]	Optimization problem to maximize the accuracy of tasks considering trade-offs against resource usage	CNNs	✓	✓	✓
	[143]	Task scheduling and offloading to optimize trade-offs between resource usage, bandwidth, and latency	CNNs	✓	✓	✓
	[154]	System for caching object recognition models at edge servers to minimize latency for object recognition	ORB	×	✓	✓
	[161]	System for pre-fetching and caching object recognition models at edge servers to minimize latency	SIFT, SURF and ORB	✓	✓	✓
	[145]	System for low-latency object recognition and tracking integrated with current AR software development frameworks	SIFT and Locality Sensitive Hashing	✓	✓	✓
Drone analytics	[175]	Lightweight and computationally inexpensive CNN for detecting vehicles from drone videos	ShuffleDet (new CNN model)	✓	×	✓
	[176]	Evaluation of CNN models on-board drones	YOLO and TinyYOLO	✓	×	✓
	[178]	Video processing from drones that saves wireless bandwidth	CNNs	✓	✓	×
	[180]	Automatic drone coordination for streaming live sports events	-	×	✓	×
	[179]	Algorithm that offloads frames from drones based on its predicted path to maximize application utility	SIFT	✓	✓	×
Vehicular	[182]	Vehicular analytics platform on cars and edge servers	CNNs	✓	✓	✓
	[185]	Estimating availability of parking spots by analyzing videos collected from smartphones in cars	Haar-like features	✓	×	✓
	[184]	System to track paths of vehicles across a network of fixed and mobile cameras	YOLO	✓	×	✓
	[183]	Cooperative distributed analytics from multiple video sources with shared data views and service composition	-	✓	✓	✓
Privacy	[186]	Crowd-sourced video analytics with user-specific privacy policies to edit/blur specific objects	Haar-like features	×	✓	✓
	[187]	Privacy-aware live video analytics that selectively blurs faces based on user-defined policies	Custom DNN-based face detector	×	✓	✓
	[188]	Privacy-aware platform for identifying and tracking humans across a network of surveillance cameras	Pipeline of three CNNs	✓	✓	✓
Live streaming	[190]	Optimal assignment of broadcasters to edge servers to minimize latency and operational costs	-	✓	✓	✓
	[193]	Selection of UEs to perform trancoding of videos; payment schemes to incentivize UEs to transcode videos	-	✓	×	✓
	[189]	System comprising UEs that transcode and distribute videos to followers in a peer-to-peer manner	-	✓	×	✓
	[192]	Optimal selection of edge servers and upload bit rates to minimize latency and maximize quality of live streams	-	✓	✓	✓

TABLE VI: Summary of works on collaborative video edge-C3.

Class	Ref.	Contribution(s)	Objective(s)	Caching	Computing	Collaboration	Mobility	SVC
SBS-assisted	[200]	Cooperative and proactive caching for multiple bitrate videos	Maximizing the linear and non-linear QoE functions (UEs' perceived QoE and received bitrate)	✓	×	✓	✓	×
	[199]	Collaborative hierarchical video caching by exploiting C-RAN functionalities	Improving cache hit rate, UE's access delay, and backhaul traffic	✓	×	✓	×	×
	[203]	Cooperative video caching and transmission in SBSs without incurring high traffic	Improving the transmission delay and reducing the UEs interference	✓	×	✓	×	×
	[202]	Joint cross layer optimization of video caching and cooperative transmission	Near-optimal caching for maximizing system throughput or minimizing delay	✓	×	✓	×	×
	[65]	Collaborative SVC video edge caching in software-defined RAN	Maximizing QoE and minimizing the video transmission costs	✓	×	✓	×	✓
	[204]	Collaborative caching and routing of 360° videos with SVC encoding	Maximizing cache hit ratio while minimizing delivery latency	✓	×	✓	✓	✓
	[205]	A synthesis-based hierarchical collaborative 360° VR caching scheme in C-RAN	Maximizing the cache hit ratio and UE QoE while minimizing the backhaul traffic	✓	✓	✓	×	×
D2D-assisted	[207]	Extending the idea of FemtoCaching by using UEs as mobile helper nodes	Improving video throughput and network capacity without deploying additional infrastructures	✓	×	×	✓	×
	[209]	Caching algorithms for D2D communication in adaptive streaming	Improving video delivery throughput in dense HetNets	✓	×	×	✓	×
	[208]	Distributed D2D video delivery scheme with respect to file size	Demonstrating the efficiency and robustness of D2D video distribution	✓	×	×	✓	×
	[210]	Smart device cache management algorithm using adaptive thresholding	Reducing unconsumed contents and video freezing under low-bandwidth conditions	✓	×	×	×	×
	[211]	Solutions to reduce the cost of video caching in device flash memory	Reducing transcoding complexity by exploiting video and flash memory physics	✓	×	×	×	×

TABLE VII: Summary of popularity-based video edge streaming and delivery approaches.

Class	Ref.	Contribution(s)	Objective(s)	Caching	Computing	Collaboration	Mobility	SVC
Video Placement	[215]	A light-weight transfer learning technique to estimate the popularity of videos	Maximizing cache hit ratio while reducing transmission cost	✓	×	×	×	×
	[216]	An online multi-armed bandit algorithm to learn context-specific popularity of videos	Increasing the cache hit rate	✓	×	×	✓	×
	[217]	A recurrent neural network which leverages UEs' content request pattern to predict video popularity and UEs' mobility	Increasing the effective network capacity and users' QoS	✓	×	✓	×	×
	[218]	A dynamic video popularity calculation method using most recent video statistics	Maximizing average online video throughput per UE close to optimal offline caching	✓	×	✓	×	×
	[219]	A video caching algorithm that leverages both short-term and long-term popularity	Maximizing the cache hit rate	✓	×	✓	×	×
	[220]	Definition of different video-specific and popularity-based similarity metrics	Maximizing the overall cache hit ratio	✓	×	✓	×	×
	[222]	A caching strategy to store prefixes of popular videos on UEs	Minimizing the average playback delay	✓	×	×	×	×
Video Replacement	[224]	A flexible ingress-efficient algorithm to enhance the LRU strategy	Increasing the caching efficiency during peak video traffic periods	✓	×	×	✓	×
	[225]	A combined proactive and reactive video-aware resource scheduling technique	Maximize the number of parallel video sessions and UEs' QoE, while minimizing stalling	✓	×	×	✓	×
	[226]	A Markov model to allocate proper cache memory space of each SBS to its UEs	Minimizing the handoffs of UEs	✓	×	×	✓	×
	[62]	A heuristic to study SVC video placement at SBSs using the RAN topology information	Minimizing the average download time under the constraint of cache size at each SBS	✓	×	×	×	✓
	[227]	A replacement algorithm for consecutive episodes of video series	Improving the cache hit ratio with lower bandwidth usage	✓	×	✓	×	×

TABLE VIII: Summary of context-aware video streaming and delivery approaches at the wireless edge.

Class	Ref.	Contribution(s)	Objective(s)	Caching	Computing	Collaboration	Mobility	SVC
Mobility-aware	[228]	A hierarchical cooperative strategy to cache vehicular UEs' popular videos in SBSs	Minimizing access latency and improving resource utilization	✓	✓	✓	✓	×
	[231]	A QoS-aware hierarchical video caching in vehicular networks	Reducing communication and relay costs while improving cache hit rate	✓	×	×	✓	×
	[229]	A video caching and streaming solution in vehicular networks based on two time-scales	Maximizing the averaged weighted sum of video quality while reducing the backhaul traffic	✓	×	×	✓	×
	[232]	Mobile vehicle video caching for low-cost video streaming services	Minimizing traffic load on cellular infrastructure without any streaming delay	✓	×	×	✓	×
	[230]	A low-cost video streaming technique by using UEs' mobility and video popularity	Reducing the backhaul traffic by 60%	✓	×	✓	✓	×
Social-based	[234]	An SVC video edge caching scheme considering the social interactions of UEs	Maximizing UE utility while improving cache hit rate and video delivery latency	✓	×	✓	×	✓
	[235]	A social-based video popularity prediction method	Jointly optimizing the video popularity accuracy and its timeliness	✓	×	✓	×	✓
	[236]	A social-based cache pricing mechanism for video edge delivery	Improving the effectiveness and reliability of video transmission	✓	×	×	✓	×
	[237]	A video distribution system based on social characteristics of UEs	Alleviating the traffic load in SBSs while achieving reliable video delivery	✓	×	×	✓	×
	[238]	Soft cache hits to recommend similar videos rather than the requested one	Reducing the mobile data traffic while maximizing the cache hit rate	✓	×	✓	×	×
View-aware	[240]	A foveated video streaming system using commodity hardware	Reducing downlink bandwidth usage	✓	×	×	×	×
	[241]	A foveated video streaming system for cloud gaming	Imperceptibly reducing downlink bandwidth requirement	×	✓	×	×	×
	[245]	End-to-end foveated video streaming for VR	Reducing downlink bandwidth	✓	✓	×	×	×
	[204]	Caching of viewports with different qualities for 360° video streaming	Minimizing the cumulative distortion experienced by UEs	✓	×	✓	✓	✓
	[242]	Viewport-aware caching policy for 360° videos	Maximizing the cache hit ratio	✓	×	✓	✓	×
	[243]	Viewport and perceptually-aware caching for 360° videos	Maximizing the cache hit ratio	✓	×	×	×	✓
	[244]	Proactive and viewport-aware streaming of 360° videos	Minimizing delay of streaming	✓	✓	✓	✓	×

TABLE IX: Summary of the works on joint optimization of video edge-C3 resource allocation.

Class	Ref.	Contribution(s)	Objective(s)	Caching	Computing	Collaboration	Mobility	SVC
QoE-driven	[246]	Edge-C3 in media cloud for on-demand adaptive video streaming	Optimizing trade-off between the storage, transcoding and bandwidth costs at the edge	✓	✓	×	×	×
	[94]	Joint optimization of SDN, caching and compute resources for streaming	Maximizing the video experience metric U-video mean opinion score	✓	✓	×	✓	×
	[247]	Joint adaptive video caching and streaming at network edge using Stackelberg game	Improving the cache hit rate and video delivery throughput	✓	×	✓	✓	×
	[80]	Network-assisted adaptive video streaming using MEC facilities	Joint optimization of QoE, fairness, and balancing the utilization of RBs among BSs	✓	×	×	✓	×
	[249]	Panoramic VR video caching and computing in millimeter wave cellular networks	Optimizing the video chunk quality, link adaptation, and adaptive viewport rendering	✓	✓	×	×	×
	[250]	Joint caching and computing of mobile VR over wireless edge networks	Optimizing joint policy to minimize average transmission rate	✓	✓	×	×	×
	[251]	Live streaming 4K videos at the edge through transient holding of segments	Optimizing number of held segments to minimize live stream latency	✓	✓	×	×	×
	[252]	User scheduling, compute and wireless spectrum allocation for live streaming	Improving UE's QoS and minimizing latency	✓	✓	×	×	×
	[253]	Allocation of caching resources to live streamers	Maximizing quality of live streams	✓	✓	×	×	✓
Revenue-driven	[254]	Cache provisioning problem in hierarchical in-network caching	Optimal cache size at different layers to minimize the cost ratio	✓	×	×	×	✓
	[37]	Optimal joint routing and caching policies using SVC and non-SVC videos in HetNets	Optimizing the trade-off between delivery costs and user experienced delay	✓	×	×	×	✓
	[255]	Joint video caching, transcoding and multicasting in virtualized HetNet	Jointly optimizing the utility of computing, caching and communication	✓	✓	×	×	×
	[256]	Joint optimization of edge caching and video sponsoring for content providers	Reducing video delivery cost while increasing the revenue of content providers	✓	×	×	✓	×
	[257]	A Stackelberg game for video delivery in commercialized small-cell caching systems	Jointly maximizing the profit of MNOs and SPs	✓	×	×	×	×
	[258]	A Stackelberg game to study cache trading in a network with an MNO and multiple SPs	Increasing the profit of SPs and improving resource allocation	✓	×	×	×	×
	[259]	A commercial video caching system consisting of single SP and multiple MNOs	Jointly maximizing the profit of the SP and MNOs while improving resource utilization	✓	×	×	×	×
	[260]	A Vickrey-Clarke-Groves auction to model cache trading in a network with selfish SPs	Improving the quality of video streaming while maximizing the social welfare	✓	×	✓	✓	×
	[261]	An action-based cache trading mechanism for SPs owning SVC videos	Maximizing the social system welfare while satisfying the economic criteria	✓	×	×	✓	✓