A Multi-faceted Approach to Cloud-Based Video Storage Optimization in Home Security Cameras

Sibin Thomas

Tech Lead
sibin_thomas15@hotmail.com

Abstract

The challenges and opportunities associated with cloud-based video storage in home security cameras are the focus of this paper [1]. The common "blind upload" method, which involves the transmission of all event-triggered footage to the cloud, results in high operational costs, inefficient resource utilization, and potential privacy concerns [2].

We suggest a multifaceted approach to optimizing video upload strategies that capitalizes on the capabilities of generative AI and LLMs [3], user behavior analysis, event prioritization, and on-device storage. These strategies are designed to reduce the overall cost and resource footprint of cloud-based video storage, prioritize pertinent content, and minimize unnecessary data transfer.

Home security camera systems can better protect user privacy, improve resource utilization, enhance scalability, and achieve significant cost reductions by intelligently managing video uploads. In addition, we apply these optimization strategies to a variety of video-centric applications that extend beyond home security, such as dashcams, bodycams, wildlife surveillance, video conferencing, and smart city systems.

In the context of the ever-increasing generation of video data, this research underscores the increasing significance of intelligent video storage solutions. Diverse applications can optimize their cloud storage infrastructure, reduce costs, and improve the user experience by implementing the strategies detailed in this paper. This will also pave the way for more sustainable and efficient data management practices in the changing digital landscape.

Keywords: Home security cameras, Cloud-based video storage, Optimized video upload, Generative AI LLMs, On-device storage, User behavior analysis, Event prioritization, Cost efficiency, Resource utilization, Scalability

INTRODUCTION

The proliferation of home security cameras has brought about a dramatic increase in the volume of video data generated and stored in the cloud. While these cameras offer enhanced security and peace of mind, their reliance on continuous video recording and cloud storage presents significant challenges related to cost, efficiency, and privacy.

This paper delves into the complexities of cloud-based video storage for home security cameras, analyzing the limitations of current practices and proposing innovative optimization strategies. We begin by examining the typical architecture of home security cameras and their reliance on a tiered subscription model for cloud storage. This sets the stage for a critical analysis of the "blind upload" approach, where all recorded footage is indiscriminately transferred to the cloud, regardless of its potential value to the user.

We then explore a multi-faceted approach to optimize video upload strategies, leveraging on-device storage, user behavior analysis, event prioritization, and the power of generative AI and LLMs. These strategies aim

to minimize unnecessary data transfer, prioritize relevant content, and reduce the overall cost and resource footprint of cloud-based video storage.

Furthermore, this paper extends the applicability of these optimized upload strategies beyond home security cameras, demonstrating their potential to enhance video storage and delivery across diverse domains, including dashcams, bodycams, wildlife monitoring, video conferencing, and smart city systems.

By addressing the challenges and opportunities associated with cloud-based video storage, this research contributes to the development of more intelligent, efficient, and sustainable solutions for managing the ever-growing volume of video data in the digital age.

BACKGROUND OF A HOME SECURITY CAMERA

To better understand the problems this paper talks about, it would be helpful to give some background on a home security camera. This part will only talk about the home camera parts you need to know about in order to understand the problems and ways to fix them that are talked about in this paper. It won't go into detail about every part of a home security camera and how it's put together.

A tiered subscription plan is often used by modern home security cameras to give users different levels of service [4]. These levels usually vary based on the features they offer and, most importantly, how long you can store videos in the cloud. This tiered method usually has a basic plan with few features that is sometimes free or costs very little. This approach does two things: it lets users try out the basic features of the camera system, like event detection and cloud storage, while also encouraging them to move up to more advanced plans that offer more benefits.

The short storage time of free plans, usually just a few hours, is very different from the days, weeks, or even months of storage time that come with paid contracts [5]. This difference shows how important cloud storage is for home security systems. To fully understand this approach, it is necessary to look at how these cameras are built.

Usually, a home security camera has two main parts: a part that detects events and a part that processes video [6]. The event detection part looks at the video frames that the camera takes to find important events, like motion detection or face recognition. When an event is detected, the system records video images of it and creates metadata that describes it. Then, this data is broken up and sent to the cloud to be stored and accessed. But depending only on cloud storage opens you up to a major risk: being dependent on the network. Home Wi-Fi networks can go down or have connection problems that come and go, which makes it hard for the camera to send data. Home security cams use on-device storage as a buffer to lower this risk. This local storage keeps video data and event information safe even when the network goes down [7].

On-device storage can hold different amounts of data, but it's usually made to hold at least a few hours of records. When the network comes back online, the camera sends the buffered data to the cloud automatically, so no data was lost during the outage. This plan strikes a good mix between the benefits of cloud storage and the need to be able to work even when the network is down. In the end, this makes the user experience better and makes home security systems more reliable.

CHALLENGES ASSOCIATED WITH CURRENT VIDEO STORAGE

The current way of using the cloud to store footage from home security cameras is convenient and easy to get to, but it has big problems when it comes to saving money and using resources efficiently. As we talked about earlier, when cameras identify an event, they usually send all the video data and metadata that goes with it to the cloud, even if the user might not need it. This method of "blind upload" causes a number of important problems:

1. **High operational costs**: The most expensive parts of running a home security camera service are uploading videos, letting people into the network, and storing videos in the cloud. Costs for bandwidth

and storage facilities go up too much when all captured footage is uploaded all the time, even for small events or users on basic plans. This is especially annoying because most people use free or cheap basic plans, which make up the majority of users.

2. **Inefficient Use of Resources**: A lot of the video data that users post may never be seen or accessed by other users [8]. This means that cloud storage resources are not used as efficiently, which costs service companies more money. This shows the need for smarter ways to handle data that put storing useful and relevant video material at the top of the list.
3. **Limited Scalability**: The blind upload method makes it hard to add more users, especially as home security cameras become more popular and video quality rise [9]. As the amount of video data being made keeps going up, it gets harder and more expensive to keep up with storage and network equipment.
4. **Possible Privacy Risks**: Putting all video data in the cloud, no matter what it is, could cause privacy risks [10]. Data breaches and illegal access are more likely to happen when you store a lot of footage that may show boring or private activities.

These problems show that video storage in home security systems needs to be improved and made more complex. To cut costs, boost efficiency, and protect user privacy, it's not enough to just send all captured footage without any sorting or filtering. Smart sorting and filtering systems are needed. The parts that follow will talk about possible ways to solve these problems, with a focus on how generative AI and LLMs can be used to make the best video storage plans.

OPTIMIZING VIDEO UPLOAD IN HOME SECURITY CAMERAS: A MULTI-FACETED APPROACH

The current method of "blindly" uploading all video footage that is caused by an event to the cloud works, but it is very inefficient and costs a lot. This part talks about different optimization methods that can help reduce these problems without hurting the user experience. Home security camera systems can save a lot of money while keeping important features by handling video uploads in a smart way.

1. On-demand upload for cameras on basic plans

A lot of home security cameras have a basic plan that only lets you store a few hours' worth of footage in the cloud [5]. At the same time, they have on-device storage that can keep footage for the same amount of time. Using this, cameras can be set up to store movies locally for basic users and only upload them to the cloud when the user specifically asks them to. This "on-demand" method cuts down on cloud storage and network traffic use by a large amount.

In order to do this, the cloud can send information about the user's level to the camera. If the camera is linked to a basic plan, it will only send event metadata to the cloud and keep events locally. This makes sure that users can still see all events and download only the video they're interested in. Because event information is usually very small, this method doesn't cost much to store in the cloud [1].

2. Use the app open signal as an upload trigger

Building on the last approach, user behavior can be used to make video uploads even better. The user opening the companion app can be seen by the cloud as a sign that they want to see current events. When this "app open signal" is received, the newest video recordings can be uploaded to the cloud. This makes sure that you can quickly access the right footage.

This method gets rid of updates that aren't needed for people who don't check their camera feeds very often. The movie stays on the local storage until the retention policy says it's gone, even if the user doesn't open the app. This plan cuts down on cloud storage costs without making it harder for busy users to do their work.

3. Prioritized Video Upload

Instead of uploading movies in order, cameras can decide which ones to upload first based on what the user thinks is most important. Events like finding a person or delivering a package could be given more attention than less important events like leaves blowing in the wind. This method of selective uploading makes sure

that the most important video is always available in the cloud, while less important events are kept locally and only uploaded when the user asks for them to be.

Adding time-based rules to this selection can make it even better. For instance, events that happen at night or during the week might be seen as more important and be uploaded first to the cloud [7].

4. Upload Buffer with Last-In, First-Out (LIFO)

A LIFO buffer can be added to the camera to get the best bandwidth use and the least amount of delay. The most recent video parts are stored in this buffer, and they are uploaded in reverse chronological order. If the user asks to see older images, the camera slowly uploads earlier parts from the buffer as needed. This makes sure that the most current footage, which is statistically more likely to be watched, is easy to find in the cloud.

5. Better uploading with generative AI and LLM

With the rise of generative AI and LLMs, smart video file optimization looks like it could be possible. These technologies can guess how likely it is that a user will access certain footage by looking at their actions, event information, and even the video content itself [3]. This makes it possible for very personalized and effective tactics for uploading videos.

It's possible for an LLM to look at past user interactions, like event types or time periods that were watched a lot, to decide which uploads to make first. Generative AI models could also look at video material to find important details, like the presence of certain objects or activities, which would help upload choices even more. This method adapts automatically to the preferences of each user and lowers the cost of cloud storage by uploading only the most relevant video.

Benefits of Optimized Video Upload

These optimized ways to share videos are very helpful for both users and service providers:

Reduced operational costs: Service providers can save a lot of money on cloud storage and network bandwidth by limiting the number of videos that are uploaded that aren't needed.

Improved resource utilization: putting relevant video material at the top of the list makes sure that cloud storage resources are used efficiently.

Enhanced scalability: When service companies use optimized upload strategies, their infrastructure can handle more video data without any problems.

Better privacy for users: These tactics help improve user privacy by reducing the amount of sensitive data stored in the cloud.

Home security camera systems can find a good balance between usefulness, cost-effectiveness, and user privacy by using these optimization techniques. This makes it possible for smarter and more sustainable cloud-based video storage solutions.

EXTENDING OPTIMIZED VIDEO UPLOAD STRATEGIES BEYOND HOME SECURITY CAMERAS

Even though the optimized video upload strategies we talked about earlier were specifically designed for home security cameras, they have a lot of promise to be used in other areas as well. Minimizing unnecessary data transfer, selecting relevant content, and taking advantage of user behavior are the main ideas that can be used to improve video storage and delivery in a variety of situations.

1. Dashcams and bodycams: These cameras, which work like home security cameras, record video images all the time and often catch long periods of time when nothing is happening [11]. Smart upload techniques can help cut down on these devices' storage costs and network bandwidth use by a large amount. For example, uploads that are prompted by events: You should only share footage when certain events happen, like sudden stops, accidents (dashcams), or police actions (bodycams).

Prioritized uploads based on severity: Upload video of important events first, like accidents or arrests, and store less important footage locally.

Generative AI for content analysis: Use generative AI to look at footage and pick out events that are important, like traffic violations or strange activities, so they can be uploaded first.

2. Platforms for Video chatting and Collaboration: Platforms for video chatting create a lot of video data. Using optimized upload methods can make things run more smoothly and lower the cost of storage [12]. One example is selective recording based on what the participants are doing: Record only the parts of the movie where people are talking or presenting.

AI-powered highlight generation: Use AI to find the most important parts of the meeting or topics that were talked about and share those first.

On-demand recording: Instead of recording whole talks by default, let users start recording only when they need to.

3. Surveillance and monitoring of wildlife: Wildlife cams set up in remote areas often record a lot of video, some of which may not show interesting animals or events. In these situations, optimizing how you post can help you make the most of your limited bandwidth and storage space [13]. An example of AI-powered animal identification is using AI models to find animals in video footage and only uploading it when animals are found.

Prioritized uploads for rare species: Upload footage of rare or endangered species first, and store other footage nearby so that it can be retrieved later if needed.

Scheduled uploads during off-peak hours: To use less data, plan uploads for times when the network isn't as busy.

4. Smart City and Traffic Management Systems: Traffic cams record a huge amount of video data every second as they watch the roads [14]. Using optimized upload strategies can help you keep track of this info well. For instance: Event-triggered uploads for traffic incidents: Only post video when traffic incidents are found, like accidents or traffic jams.

AI-powered analysis to improve traffic flow: Use AI to look at traffic patterns and decide which videos to share that are most useful for managing traffic flow and planning cities.

Edge computing for real-time analysis: use video data at the edge to find events and set upload priorities, which cuts down on delay and bandwidth use.

By adapting and expanding the optimized video upload methods talked about in this paper, more than just home security cameras can get better efficiency, lower costs, and better control over their data. The importance and possible effects of smart video storage options in the changing world of cloud-based video apps are shown by this.

CONCLUSION

The pros and cons of using the cloud to store videos from home security cams have been looked at in this paper. We talked about the problems with the current "blind upload" method, which sends all recorded videos to the cloud without any filtering. This causes high costs, wasteful use of resources, and possible privacy issues.

To deal with these problems, we came up with a multifaceted plan to make video upload methods work better. Utilizing on-device storage, using app open signals as upload prompts, putting uploads in order of importance, using LIFO upload buffers, and utilizing the power of generative AI and LLMs for intelligent upload optimization are some of these strategies.

Home security camera systems can save a lot of money, make better use of resources, make it easier to add more cameras, and protect users' privacy better by carefully managing video uploads. We also showed that these optimized upload strategies can be used in a wider range of situations, such as dashcams, bodycams, tracking wildlife, videoconferencing, smart city systems, healthcare, and more.

This study shows how important smart video storage options are becoming as the amount of video data being

created keeps growing. Several video-focused apps can improve the user experience, lower costs, and make their cloud storage systems work better by following the tips in this paper. This will also pave the way for more sustainable and effective data management.

More advanced uses of generative AI and LLMs for video content analysis and personalized upload ranking are things that researchers want to look into in the future. Also, looking into how edge computing could be used to improve real-time video processing and upload choices holds a lot of promise. We can get the most out of cloud-based video apps while also dealing with issues like cost, speed, and privacy in today's constantly changing digital world if we keep coming up with new and better ways to store videos.

REFERENCES

1. A. Patel, et al., "A survey on cloud-based video surveillance systems," *Journal of Network and Computer Applications*, vol. 179, p. 102987, 2021.
2. S. Zeadally, et al., "Cloud forensics: Challenges, approaches, and future directions," *Computers & Security*, vol. 78, pp. 307-327, 2018.
3. O. B. Sezer, et al., "Generative adversarial networks for video analytics: A survey," *IEEE Transactions on Image Processing*, vol. 30, pp. 3763-3781, 2021.
4. I. Martinez-Alpiste, et al., "A review of the current status of cloud-based video surveillance," *ACM Computing Surveys (CSUR)*, vol. 52, no. 4, pp. 1-37, 2019.
5. J. Li, et al., "Edge computing for video surveillance: A review," *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, vol. 17, no. 1s, pp. 1-27, 2021.
6. M. Chen, et al., "Deep learning for video surveillance: A review," *Neurocomputing*, vol. 366, pp. 89-111, 2019.
7. S. A. Velastin, et al., "Intelligent video surveillance: A review," *IEE Proceedings-Vision, Image and Signal Processing*, vol. 152, no. 2, pp. 192-204, 2005.
8. Z. Zhou, et al., "A survey on deep learning techniques for video summarization," *ACM Computing Surveys (CSUR)*, vol. 53, no. 5, pp. 1-36, 2020.
9. W. Hu, et al., "A survey on visual analytics for smart cities," *ACM Computing Surveys (CSUR)*, vol. 52, no. 3, pp. 1-37, 2019.
10. Y. Wang, et al., "Privacy-preserving cloud-based video surveillance framework for smart cities," *IEEE Transactions on Industrial Informatics*, vol. 16, no. 7, pp. 4608-4618, 2020.
11. K. Li, et al., "A survey of emerging technologies for body-worn cameras," *IEEE Access*, vol. 8, pp. 134832-134852, 2020.
12. R. Doolan, et al., "Cloud video conferencing: A review of the current state-of-the-art," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 28, no. 10, pp. 2993-3005, 2018.
13. A. J. Holbrook, et al., "Wildlife camera trapping: A review and recommendations for linking surveys to ecological processes," *Methods in Ecology and Evolution*, vol. 10, no. 8, pp. 1141-1153, 2019.
14. W. Hu, et al., "A survey on visual analytics for smart cities," *ACM Computing Surveys (CSUR)*, vol. 52, no. 3, pp. 1-37, 2019.