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QoS-adaptive service configuration framework for cloud-assisted video surveillance systems

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Abstract Quality of service (QoS)-adaptive service configuration is crucial for seamless access to video services in cloud-assisted video surveillance systems. To maintain seamless access to video on a user's preferred device, suitable video transcoding services are needed. It is a challenging task to choose and configure these services for various devices to ensure QoS-adaptive user experiences. To configure these services for the desired user devices, a suitable configuration algorithm is needed. Therefore, this paper describes a QoS-adaptive service configuration approach to choose

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the optimal configuration for the preferred user devices in varied contexts so that the user can access the services ubiquitously. We implemented a cloud-assisted video surveillance prototype to show how the proposed method can handle ubiquitous access to target video for possible QoS-adaptive and video processing requirements in terms of bandwidth, delay, and frame rates. The results show that the proposed configuration method outperforms the other comparable approaches.

Keywords Adaptive QoS · Cloud-assisted video surveillance · Service configuration · Transcoding service

1 Introduction

Today, a large number of companies provide video surveillance services (VSS) to customers. These services often require local or cloud servers to collect, analyze, summarize, process, store, and deliver video content to the user. However, because of the diversity of user mobility and device capabilities with regard to quality of service (QoS) adaptiveness (e.g., resolution, computation, framerate, and bandwidth), it is a formidable challenge to deliver the desired video content based on a surveillance user's demands. To overcome this challenge, several methods such as video transcoding [16, 17], repurposing [11], media selection [22], composition [8], configuration [26], and summarization [4] services have been proposed.

Among these methods, video service configuration or composition is a viable solution to providing video content delivery with high playback quality. A service configuration or composition can be defined as an aggregation of media services with similar functionality. The services are selected from a pool of services (e.g., video capture, streaming, transcoding, and viewing services) that are delivered by various application service providers running on a local or cloud server. Original video is recorded by a video detection service and streamed to the required composite transcoding service by streaming service. The composite transcoding service consists of a number of primitive transcoding services that must be selected from different cloud resources to produce the video content the client requests. Normally, most systems consider configuring a single transcoding service along with a streaming service and video detection service to fulfill users' needs.

However, because of the proliferation of emerging mobile video services, the use of a single transcoding service from clouds is insufficient and could be unable to provide the required services. In such a case, it is difficult to determine the optimal service composition sequence that can fulfill users' demands.

To select the optimal services, previous studies [10, 13, 19, 20, 28, 30] have used different search-based approaches that are based on conventional linear programming, ant-based, or hybrid (ant-genetic) [13] techniques. Qi et al. [20] proposed a QoS-based service composition technique for cloud environments. Ye, Zhou, and Bouguettaya [28] used a genetic-oriented approach for their service composition in a cloud-supported environment. In [30], a combinatorial and artificial intelligence based approach was used to compose simple web services from multiple clouds. Zeng et al. [29] proposed a cloud-based composition matching algorithm based on a simple web service where execution time is used to measure the QoS. These studies do not really consider multimedia-related QoS or QoS adaptiveness with respect to multimedia surveillance applications, particularly for video surveillance.

This paper proposes a QoS-adaptive service configuration framework for a cloud-assisted video surveillance system (VSS). The framework is one of the few attempts to solve the

challenges of providing QoS-adaptive video processing in Video Surveillance as a Service (VSaaS) [18]. We present a QoS-adaptive selection algorithm to determine a suitable configuration in a cloud-assisted VS environment. The suitability of the proposed approach is evaluated through implementation and simulation. Experimental results show the effectiveness of the proposed service configuration in terms of QoS.

The rest of this paper is organized as follows. In Section 2, we review related state-of-the-art methods. In Section 3, we present our proposed service configuration framework. We then briefly describe performance comparisons in Section 4. We provide our conclusions in Section 5 along with possible future research directions.

2 Related studies

Video surveillance is a mature research domain. There are many existing studies related to VSSs [1, 8, 16, 17], which mostly involve conventional local or centralized surveillance systems. There are only a few cloud-based surveillance systems studies [2, 5–7, 9, 14, 18, 21, 23–25].

Hossain et al. [14] proposed a cloud-based resource allocation technique for surveillance systems. This system obtains pictures from camera sensors and transmits them to Amazon's Elastic Computing Cloud (EC2) for possible composition so that the user can obtain the video based on their preferences. This task depends on a suitable resource configuration to guarantee the right resources for the surveillance users. To optimize the resource configuration, linear programming and heuristics algorithms are used.

Hassan et al. [5, 6] proposed a scalable and elastic cloud-assisted publish/subscribe model for IPTV VSSs. The study's main focus was how to match the surveillance event with the subscriptions in the cloud platform. Rodríguez-Silva [21] proposed a modular VSS based on cloud computing technologies that provides highly reliable solutions for different storage providers. Traditional client–server architecture poses some challenges to scalability and storage that can be alleviated by the use of cloud-based VSSs. The system obtains media streams generated by cameras in the cloud, optimizes transmission according to the network conditions, and stores them in a secure way [21]. To optimize video delivery to users with respect to QoS adaptiveness, different approaches are used. Some of the approaches related to web service composition are not directly applicable to video service composition or configuration; however, QoS optimization techniques can be adapted for video service selection or configuration. Some of the related studies are briefly described below.

A dynamic web services composition algorithm was proposed by combining an ant colony optimization (ACO)-based algorithm with a genetic-based algorithm. The combined algorithm consists of an optimal path for a directed acyclic graph, which has advantages for web services composition [27]. Cui et al. proposed a system that uses genetic-based optimization to satisfy the QoS requirement [3]. An ant-based global optimization algorithm has the potential to solve QoS routing constraints more effectively and efficiently for multimedia applications [12, 15]. The proposed system is based on an ant's capability to find the shortest path from its nest to a food source [22]. A QoS-aware, dynamic web services composition optimization algorithm with improved ACO was also proposed. The essence of this algorithm is that the problem

of dynamic web service selection with QoS criteria towards a multi-objective multi-choice QoS-aware, web services composition optimization [22].

This study was motivated by the cloud-based surveillance framework of Hossain [9]. However, our approach is distinct in different ways. First, we adopt a QoS-adaptive service composition approach using cloud computing as a support infrastructure. Previously, Hossain [7] attempted to investigate the appropriateness of cloud-based surveillance systems; however, we consider QoS adaptiveness when selecting the best service configuration for different VSS users' settings and measure the EC2-based workload in terms of video detection, streaming, and transcoding.

3 Proposed cloud-based QoS-adaptive VSS

A high-level view of the proposed cloud-based QoS-adaptive VSS is shown in Fig. 1. The main components of the proposed system are described below.

3.1 Surveillance user and viewing service

The client can view surveillance video allowed by their subscription. Based on this subscription, the desired video content is streamed to his/her device. A user may be a home user, security personnel such airport security, police officer, fire service officer, or other type of user.

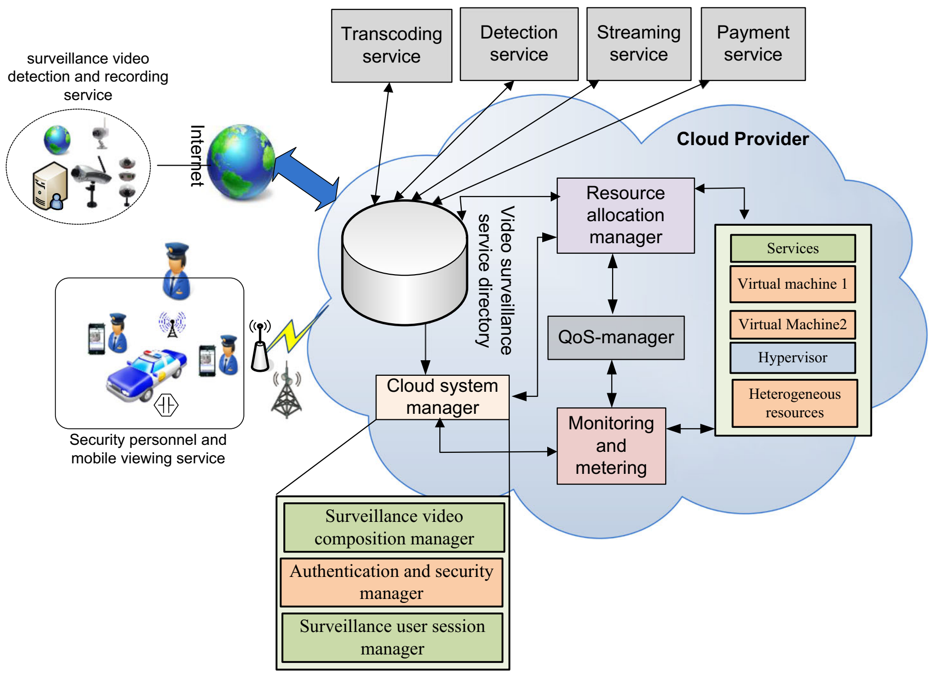


Fig. 1 Proposed QoS-adaptive cloud-assisted VSS

3.2 Cloud system manager

This component is responsible for the overall control and management of the system. It also manages all Virtual Machines (VMs) and allocates suitable resources for each service through a resource allocation manager.

3.3 Streaming service

The Streaming Service can be regarded as a server where the video stream is composed and transmitted either directly to a client or to a transcoder to transcode the video stream according to a user's request. The streaming server comprises a web service, Remote Method Invocation (RMI) service, and QoS-manager subsystem along with a QoS-adaptive selection and composition approach.

3.4 Transcoding service

The transcoder is a service that receives a video stream as input and provides the desired QoS-adaptive stream to the user. This service consists of transcoding web services, RMI services, and a link to the QoS-manager for possible service compositions.

3.5 VSS service directory

This directory acts as a registry such as a Universal Description, Discovery, and Integration (UDDI) to store images and videos from the Surveillance Video Detection and Recording Service (described below). This directory also registers and publishes different participating services to their corresponding locations in the network.

3.6 Surveillance video detection and recording service

This detection service is used to record and store live and pre-encoded videos and images from cameras with different resolutions (CIF and QCIF), bit rates, and frame rates.

3.7 QoS manager

The QoS Manager is responsible for ensuring the QoS adaptiveness of the user's video after selection and configuration of the required services (e.g., video detection, streaming, and several transcoding services).

Given a video transcoding service network $G_T=(N,L)$, where N be the number of transcoding service nodes and L be the set of service links. Every link corresponds to several quality values represented by a quality vector q_v:$<q_1,q_2,\cdots q_m$ highlighting the quantifiable values of the quality terms such as delay, bandwidth, frame rate, and other video related QoS parameters as shown in Fig. 2.

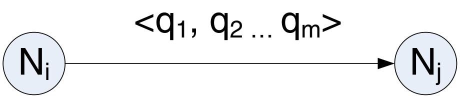


Fig. 2 Multi-valued link in terms of QoS

In order to differentiate one link over another, we estimate a score for each link in terms of quality metrics by:

$$S_1 = \sum_{k=1}^{m} w_k q_k \tag{1}$$

where $W_1, W_2, \cdots W_m$ be weight of the corresponding quality term and $\sum w_k = 1$.

The QoS-adaptive service configuration problem is to select or choose the best path $P_T(s,d)$ from a source node s to a destination node d such that the score of the path P_T has the maximum value:

$$\begin{array}{l} \textit{Find a path } P_T \textit{ with maximum QoS score, i.e.} \\ max \sum S_{l,\ where}\ l \in P_T \end{array} \tag{2}$$

Fig. 3 QoS-adaptive service configuration algorithm

Algorithm 1 QoS-aware Service Configuration

```
Input: Source node s , Transcoding service  network (GT)
QoS requirement Qq:< q1,q2, .... qm >
BEGIN
        Determine the set of service nodes (dp) that can
        satisfy the given QoS requirement where dp  ⊂  N
        for each node v   do
        in GT
            dist[v]: = infinity
            Previous[v]:= undefined
        end for
        dist[s]:= 0
        Qu:=the set of all nodes in
        Graph
        While Qu is not    do
        empty
              u := vertex in Qu with smallest distance in
              dist[]
              If dist[u] = infinity
              then
                break
              end if
              remove u from Qu
              for each neighbor    do
              v of  u
                alt := dist[u] + dist between(u, v)
                if alt < dist[v] then
                   dist[v]:= alt
                   previous[v]:= u
                   decrease-key v in Qu
                end if
              end for
        end while
        for each node u   do
        in dp
             cost[u]:= dist[u]
        end for
        dn : = Mint(cost[])
        path from node s to node dn is selected  for the
        service configuration
END
```

subject to following QoS constraints,

$$Q_O S_r \leq Q_O S_a$$

Where, $Q_O S_r$ and $Q_O S_a$ denote available and required QoS.

$$D = \sum_{j=1}^{n} D_i = 1 \quad (3)$$

The service path is chosen in such a way that it can satisfy the given QoS requirements such as delay in ms, frame rate per second, resolution (e.g., CIF or QCIF), and bandwidth in kbps.

The best configuration path is the path that has the highest cumulative score and satisfies QoS. Let GT be a directed graph based on transcoding nodes and associated links. Figure 3 shows the service configuration approach.

The algorithm at first identifies a set of potential service nodes dp that satisfies the given QoS requirement. To determine the transcoding configuration path, the algorithm requires a cost between each link. However, earlier in the problem statement, we use QoS score instead of cost to define the link usefulness. QoS score is converted to cost by taking its inverse, i.e.,, $\mathrm{cost}_l = \frac{1}{s_l}$. The shortest paths are then discovered from source node s to all potential service delivery nodes dp. The path with the lowest cost is selected for the service configuration. This path shows the transcoding sequence for that particular media. In the next section, we measure some of the workload for processing different services (e.g., video transcoding, detection, and streaming) because cloud-based VSSs consume large amounts of resources in terms of CPU, bandwidth, and memory.

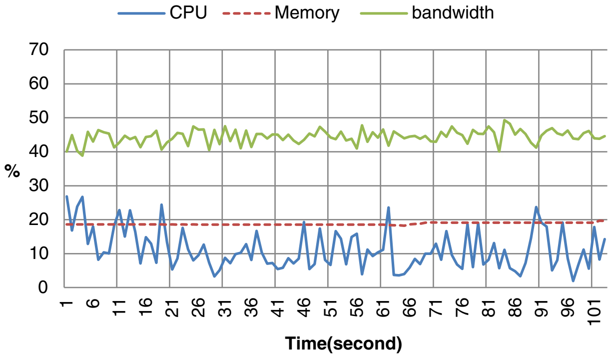
4 Simulation and performance comparisons

Cloud-based video surveillance workload is difficult to quantify. To simplify the task of workload selection during service configuration, we have selected three key media services that are involved in video surveillance workload calculation and implementation.

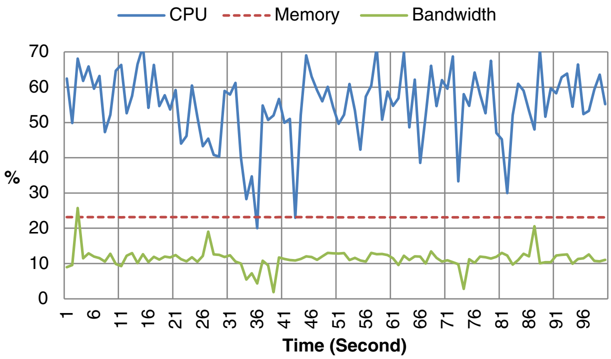
4.1 Video surveillance service workload

Figure 4 shows the workload of the two main services used for service configuration in the proposed QoS-adaptive VSSs. We concentrated on two key services: video streaming and repurposing (or transcoding). To understand the features of these two video content-related workloads, we collected their run-time statistics by running the proposed video surveillance prototype on Amazon's EC2. For this purpose, we used an M1 Small VM equipped with one Intel® Xeon® E5430 2.66 GHz CPU unit, one CPU core, 1.7 GB memory, 1 Gbps bandwidth, and 30 G hard drive running 64-bit Microsoft Server 2008. The Windows performance monitor was used to capture the resource use of the workloads in terms of CPU, memory, and network bandwidth. Figure 4 also shows the resource use of said workloads over time. As can be seen, there are significant differences among the workloads in terms of resource use

Fig. 4 Workloads of the two main video surveillance services (a-b)



a Surveillance Video Streaming



b Video Repurposing/Transcoding

4.2 Run time comparison

In this section, the proposed service configuration algorithm is compared with an ACO-based algorithm [8] and genetic-based algorithm [28]. This runtime comparison considers session request rate. To generate the network topology, a similar simulation environment as the one described in [12] was used. As shown in Table 1, the proposed algorithm is marginally faster than the competitive algorithms.

Table 1 Run time comparison (Session request rate)

Session request rate	Proposed algorithm	Genetic algorithm	Ant-based algorithm
10	723	810	921
20	1121	1089	1822
30	1520	1628	3012
40	2723	2695	3302
50	3621	3721	4120

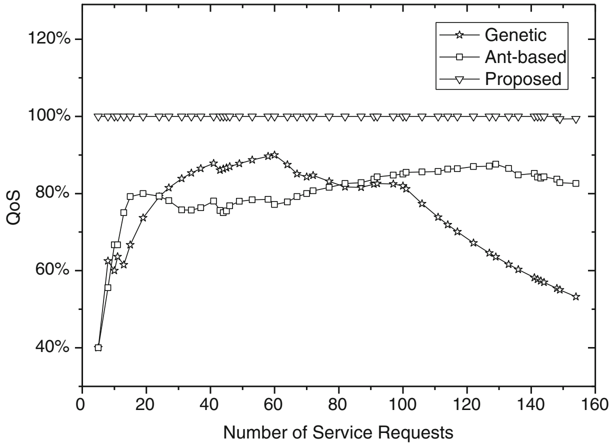


Fig. 5 Average QoS

4.3 Performance comparison through simulation

In this section, we measure the QoS success rate and average delay of our proposed approach and two comparison approaches.

4.3.1 QoS success rate

As shown in Fig. 5, the proposed algorithm attains a higher QoS success rate than the others. For both other approaches, the QoS success rate decreases radically after 100 service requests because of their 100 service requests limit. The extra service requests must wait in the queue, indicating that there might a QoS violation. The ant-based approach sustains an average 80–85 % success rate with random server selection; however, after 100 requests, the QoS success rate decreases. The QoS success rate in the genetic approach also drastically decreases if the number of service requests

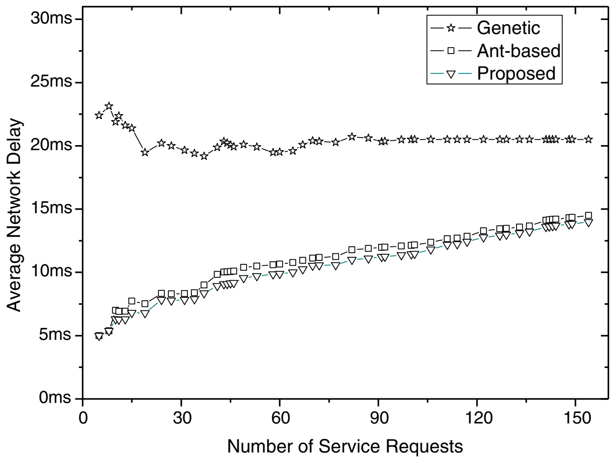


Fig. 6 Average network delay

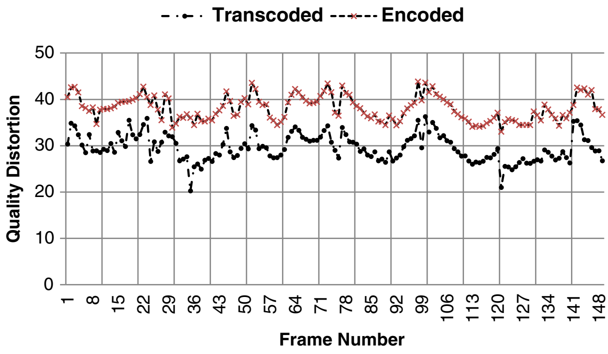


Fig. 7 Video quality distortion

exceeds 100. However, our approach sustains its success rate until the end of the experiment (150 service requests). When there are only a few service requests, the composite QoS requirement can be fulfilled by a load balancing approach because physical servers with very low individual delay are selected. However, the service/server dependencies must be considered when the workload increases to a certain level. At that point, the physical servers with very low individual delay are already occupied. Thus, the load balancing approach is more likely to violate the QoS requirement without exploring the dependencies of the services and servers.

4.3.2 Average delay

We evaluated the proposed algorithm and compared it with others in terms of average delay and QoS. In simulations, we measured the average delay under different numbers of service requests ranging from 1 to 150. Figure 6 shows the average delay of the services measured for each of the three approaches. The results show that the proposed method has a lower average delay than that of the other two approaches.

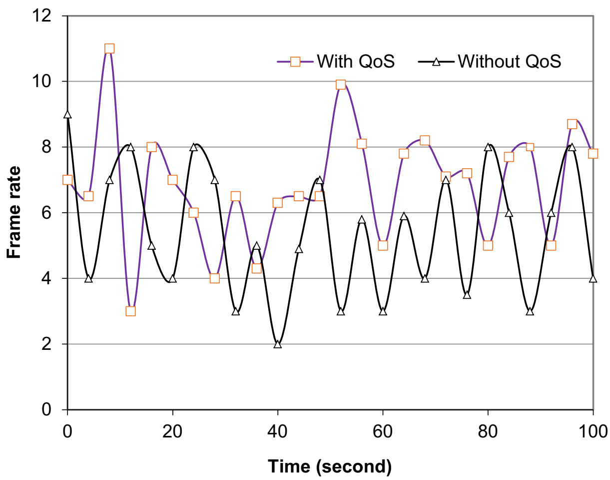


Fig. 8 Video frame rate comparison

These methods could perform better if they considered delay optimization in their composition process.

4.3.3 Video quality distortion

In the quality distortion experiment shown in Fig. 7, the surveillance video quality distortion is measured in terms of Peak signal-to-noise ratio (PSNR) by comparing the encoded and transcoded bit streams. In this case, H.263 was considered, encoded at 128 kb/s, and transcoded at a 64 kb/s. A distortion in quality of 1.24 dB was found.

4.3.4 Video quality comparison based on framerate

Figure 8 shows the video playback quality in terms of PSNR for the video detection and recording service QoS. Because of bandwidth variations, the frame rate for the surveillance users also fluctuates, updates suddenly, and provides inaccurate results at various times. Hence, QoS control strategies may be one option to ensure seamless video playback.

5 Conclusions

Cloud-assisted video surveillance is emerging as a notable service that can deliver low-cost effective surveillance services to diverse users from anywhere, anytime, and on any device. However, one major challenge for cloud-based video surveillance providers is to provide surveillance services that are QoS adaptive. This paper describes a QoS-adaptive service configuration approach. The results show that the proposed approach outperforms some state-of-the-art approaches in terms of QoS guarantee, low delay, and video playback quality. Because a cloud-based system consumes a large amount of resources, workload experiments using the proposed system were performed on EC2 to determine its suitability. In future, we will consider additional work load parameters and costs with regard to execution time.

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