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A Heuristic for Quality Aware Admission Control for Gesture Based Video Streaming over Ubiquitous Networks

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Abstract: A Quos aware model for streaming multiple heterogeneous multimedia services over ubiquitous networks is presented whose aim is to simultaneously support as many service streams as possible and to optimally guarantee all users' Quos within these environments. This paper proposes a novel admission control algorithm, in conjunction with a quality adaptation scheme, which is capable of effectively guaranteeing and improving the service quality. Upon examination of the simulation results, we conclude that the proposed model and schemes provide valuable guidelines for the planning of future ubiquitous networks and multimedia systems.

Key words: Streaming Multimedia · Admission control · Ubiquitous networks · QoS

INTRODUCTION

Characterization of providing admission control scheme to heterogeneous multimedia services has been focused considerably in recent years. Nevertheless, an extensive body of previous work generally assumes that the traffic arrival models are established in advance (e.g., Markov modulated Poisson process (MMPP) in [1], lognormal distribution in [2], etc.). Multimedia streaming services, in general and video streaming services, in particular, are characterized by stringent delay constraint, which cannot be neglected. Furthermore, QoS provisioning problems of ubiquitous networks with heterogeneous multimedia services are far from complete even if the reduction of network congestion is ensured. Therefore, one of the most challenging aspects is the quality of service (QoS) provisioning for multimedia real-time applications [3]. Thus, how to effectively allocate the bandwidth resource for each admitted quality adaptive multimedia stream must be determined, especially when a large number of unpredictable stream sessions are simultaneously admitted into the network.

This paper proposes a heuristics for quality adaptive admission control over ubiquitous networks. The purpose is to maximize the QoS of all networked users on condition that the congestion is reduced in the large. We slightly modify the network calculus based admission control algorithm of Liang Tang *et al*. [4], for QoS optimization of all admitted users. Experimental examples reveal that the proposed heuristics is efficient on improving the admitted users' QoS and bandwidth utilization, which paves the way for designing future ubiquitous multimedia communications systems.

Ubiquitous Network System Model: The heterogeneous network model shown in Figure 1 consists of many senders with multiple streams of multimedia traffic that is streamed to heterogeneous receivers that are able to handle and control multimedia service streams viz., on demand traffic like Video on Demand and broadcast services (that consists of layered video) like IPTV channel through a gateway. A QoS manager present in the gateway network is responsible for admission control in order to provide QoS guarantees for the multimedia services. We devise a heuristic for quality adaptive admission control to decide the streams to be transmitted to the receiver.

Definitions: Consider a continuous-time multimedia stream model, which can be characterized by a cumulative curves-theoretic methodology under the name of network calculus [5].

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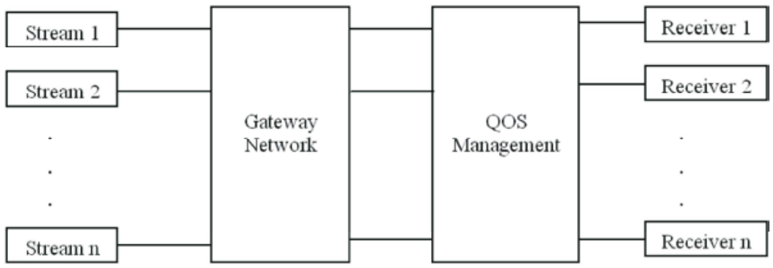


Fig. 1: Heterogeneous network model for QoS management

Let A(t), D(t) and D_{min}(t) denote the stream arrival process, stream departure process and minimum stream departure process, respectively that are non-negative, wide-sense increasing and right-continuous functions with $A(0) = D(0) = D_{min}(0) = 0$ similar to [6].More precisely, we have the following definitions.

Definition 1 (Stream Process): Stream arrival process: A(s, t) = A(t) - A(s), ◎ 0 = s = t represents the cumulative amount of multimedia stream (in number of bits) that will arrive at the gateway during time interval [s, t];

- Stream departure process: D(s, t) = D(t)-D(s), ◎ 0 = s = t represents the cumulative amount of multimedia stream (in number of bits) that will depart from the gateway during time interval [s, t];
- Minimum stream departure process:

$$D_{min}(s,t) \equiv \min_{s,t}\{D(s,t)\}, \forall 0 \le s \le t$$

Definition 2 (Stream Service Curve): service curve β(t) for a multimedia stream specifies a lower bound on the service rate given to the stream, namely the quantity A◎β(t) represents the minimum data that must flow out of the gateway, where the operator ◎ is convolution in the min-plus algebra, i.e.,

$$(a \otimes b)(t) \triangleq \inf_{0 \le \tau \le t}\{a(\tau) + b(t-\tau)\}$$

According to Definition 1, the following inequality holds, i.e.,

$$A(t) \ge D(t) \ge D_{min}(t), \forall t \in R^+ \triangleq (0, \infty)$$

In addition, it can be verified from Definition 2 in network calculus literature that given a multimedia stream arrival process and a corresponding minimum departure process, the service curve β(t) and its minimum service rate μ_{min} satisfy,

$$D_{min}(t) = A \otimes \beta(t), \mu_{min} \triangleq \lim_{t \to \infty} \frac{\beta(t)}{t}$$

Definition 3 (Stream Quality Levels): A multimedia service stream's quality level set is denoted by Q = $\{Q_l | Q_1 < \ldots < Q_L\}$, where $M \in Z^+$ is the number of levels available and Q_l represents the effective bandwidth corresponding to encoding $l \in \{1, \ldots, L\}$.

In Definition 3, the quality level Q_l may correspond to the sum of the first l layers in hierarchical encoding. Moreover, it has been confirmed that "L" in the region of three to five is enough to have reasonable fairness [7].

Generally speaking, modeling such optimal quality adaptation for multiple concurrent streams is a difficult problem and still seems exploratory. Hence, the definition of QoS function is not unique. Several quantifiable means of assessing QoS have been studied in the context of distortion, e.g., peak signal to noise ratio (PSNR) in [8]. However, these functions are in general nonlinear functions of the encoding rate. Thus, a linear approximation alternative is considered, which has been shown from the experiments to be capable of reducing the computational complexity significantly [9, 10]. Motivated by this, the QoS function is defined as follows.

Definition 4 (QoS Function): The QoS function of a multimedia service stream is denoted by.

$$\varphi(t, Q_l(t)) \triangleq \frac{1}{t-T}\int_T^t \frac{Q_l(t)}{Q_1} d\tau$$

where $Q_l(t) \in Q$ is the quality level of the service stream at time t > T defined by the Definition 3. $T \in R^+$ represents its admitted time and $\varphi(t, Q_l(t) \le 1$.

Definition 5 (Maximum Horizontal Distance): Let $g_1(t)$: $R^+ \to R^+$ and $g_2(t)$: $R^+ \to R^+$ be two functions. A term H (g_1, g_2) is said to be the maximum horizontal distance between g_1 and g_2, if.

$$H(g_1, g_2) = \sup_{v \ge 0}\{in\{\varsigma \ge 0 : g_1(\upsilon) \le g_2(v + \varsigma)\}\}.$$

With Definition 5, the deadline constraint in terms of time difference in Fig. 3 can be evaluated by computing the maximum horizontal distance between stream arrival process and minimum stream departure process. Then, we have d (t) $\leq$ H (A, β); with d (t) the virtual delay (for details, see [11]).

Heuristic for Quality Adaptive Admission Control: Suppose that there are N(t) multimedia service streams being served in a work-conserving gateway, of which the bandwidth capacity is limited and upper bounded by a constant C at time t $\in R^+$.

Consider the media information I (including quality level set Q) is carried by incoming stream. Denote AQ_1 as the arrival process corresponding to a quality level $A_{ll} \in Q$. Note that the better multimedia quality is, the greater bandwidth requires. Thus, a service curve $\beta^i(t)$, or equivalently, a lower bound on the service rate μ given to the multimedia stream can be determined, which meets the play-out deadline requirement. More precisely, the minimum service rate $\mu_{min}^{Q_l}$ that satisfies the calculus-based service conditions can further be derived as follows,

$$\mu_{min}^{Q_l} = \inf\{\mu \geq 0 : A^{Q_l} \otimes \beta^{\mu}(t) \geq D_{min}^{Q_l}(t)\} \quad (1)$$

In practice, however, an approximate minimum service rate should be chosen through (1) by an iterative computing method such as in [12].

The pseudo code for the heuristics of admission control is described in Algorithm 1.

Algorithm 1: Heuristics for admission control

I/P: Incoming set of multimedia streams
O/P: Streams with selected layers for transmission
Line 1: Calculate the service rate μs_c
Line 2: for existing stream i =1 to N(t)
Line 3: do obtain current service $\mu_i^{Q_l^i}$
Line 4: end for
Line 5: Calculate leftover BW
Line 6: $C_{left} = C - \sum_{i=1}^{N(t)} \mu_i^{Q_l^i}$
Line 7: if $\mu s_c < C_{left}$ then
Line 8: for j = L to 1
Line 9: if $\mu_{sc}^{Q_j^{sc}} < C_{left}$
Line 10: select Q^{sc}_j
Line 11: break;
Line 12: end for
Line 13: else
Line 14: for existing stream i=1 to N(t)
Line 15: obtain service requirement $\mu_i^{Q_{l-1}^i}$
Line 16: end for
Line 17: Calculate maximum virtual leftover BW
Line 18: $C_{max} = C - \sum_{i=1}^{N(t)} \mu_i^{Q_{l-1}^i}$

Line 19: If $\mu_{sc}^{Q_1^{sc}} < C_{max}$

Line 20: select $Q_{l_i-1}^i$ and Q_1^{sc}
Line 21: end

Initially, the incoming stream N(t) is obtained, based on which the service rate μ_{sc} can be calculated. Through the evaluation of the available bandwidth "C", leftover bandwidth "C_{left}" and maximum virtual leftover BW "C_{max}", the corresponding enhancement layers are selected for transmission such that current service rate of the stream with chosen enhancement layer is less than the maximum virtual leftover bandwidth.

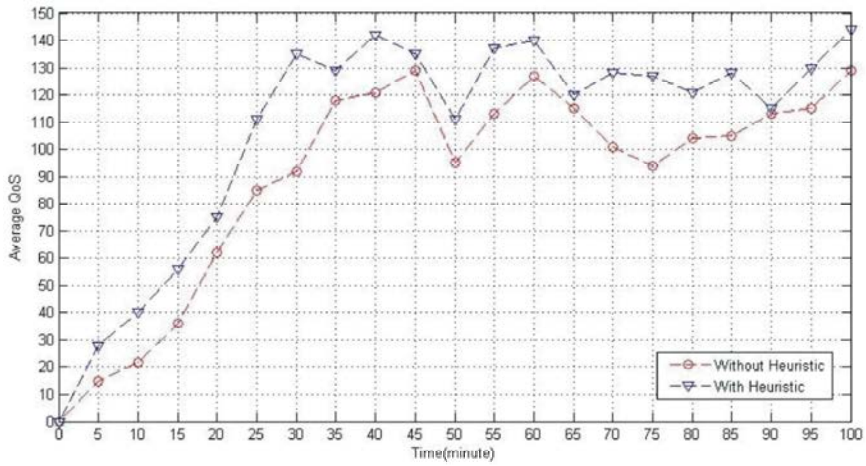
Performance Analysis: Simulations were performed to investigate the performance of the optimal adaptation policies under the assumption that stream durations are known and unknown. Consider a heterogeneous multimedia network system which supports both broadcast and on-demand services. Assume the inter-arrival time is exponentially distributed and the simulation time is set to 100 minutes.

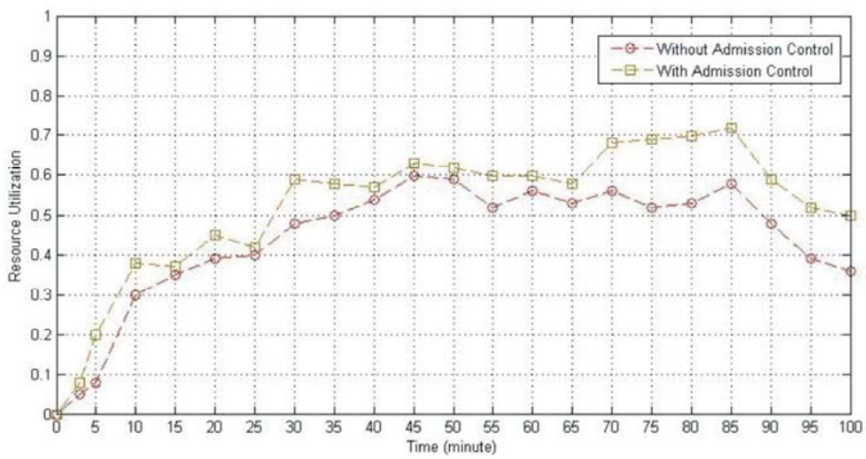
For broadcast streams, every channel is divided into five substreams (equivalently, five layers corresponding to the quality level set Q = $\{Q_l | Q_1 < . .. < Q_5\}$). Table 1 shows the simulation configuration parameters.

Let λ_{vod} and λ_{bc} devote the arrival rates of on-demand and broadcast type multimedia streams respectively. Let the total number of channels be denoted by "k" . For simulation, we consider C = 50Mbps, $\kappa = 20$, $\lambda_{vod} = 10$, $\lambda_{bc} = 10$. Fig. 5 shows the aggregate users' QoS and resource utilization of the network. From Fig. 5a, it can be observed that by implementing the admission control heuristic and selecting the optimal layers at every quality adaptation time, the aggregate users' service quality is significantly enhanced. Moreover, the resource utilization is improved as illustrated in Fig. 5b.

Table 1: Simulation Configuration Parameters

Parameter	Value
Each simulation time	60 min
Per-stream sojourn time	700 - 1800 sec





CONCLUSION

We present a model for QoS provisioning in ubiquitous networks with heterogeneous multimedia services where a QoS manager adapts the compression level of the stream to match with the available network bandwidth to cater maximum number of client requirements with guaranteed users' perceived quality. We devise a calculus-based admission control heuristics for the same. Experimental results reveal that the proposed model is efficient on improving QoS and bandwidth utilization, which paves the way for designing future ubiquitous multimedia communications systems.

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