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MODELING SERVICE QUALITY AND BENEFITS OF MULTI-SERVICE ARCHITECTURES IN ROAD TRANSPORT TELEMATIC APPLICATIONS

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ABSTRACT

Modeling benefits and Quality of Service (QoS) for Multi-Service Architectures (MSAs) is important to enable service providers offer the best Transport Telematic Services (TTSs) with high societal benefits to users. This study models how different QoS characteristics may influence potential benefits of MSAs for road based freight TTSs. This is achieved by modeling the QoS degradation under conditions of shared resources and including costs associated to such degradation to determine the benefits as the difference between the costs and societal value of the applications. A system performance oriented QoS measure has been introduced in coming up with a MSA benefits model, providing a possibility to capture different quality attributes, desired performance levels, and even the possibility to introduce desired priorities between applications and quality attributes.

Keywords: Quality of Service, Multi-service architecture, benefits.

I. INTRODUCTION

The purpose of this study is to model how different Quality of Service (QoS) characteristics such as timeliness, availability, accuracy and completeness may affect the costs and hence potential benefits of Multi-Service Architectures (MSAs) for road based freight Transport telematic Services (TTSs). Transport Telematic Applications (TTASs) must meet a certain level of performance in order to be beneficial to the society. Such performance will affect the quality of the resulting services. The underlying concepts of bandwidth, throughput, timeliness (including jitter), reliability, perceived quality and cost are the foundations of what is known as QoS and has mostly been addressed in relation to telecommunication system efficiency [1]. MSAs on the other hand are essentially system platforms with the potential capability to support multiple services [5], [7] such as Electronic Fee Collection (EFC) system platforms and hence improve benefits through resource sharing. An earlier study addressed benefits of MSAs for achieving a range of TTSs in the context of road freight transport [7].

Because of their potential to improve overall system benefits by providing functionalities that can be shared between different applications, MSAs have gained a lot of interest in different areas ranging from internet applications to ITS applications [5], [7], [15], [16]. With an increasing number of new applications in transport telematics based on wireless communication infrastructure, it is necessary to analyze MSA benefits in the context of shared resources. While resource sharing may increase total system benefits, the eventual outcome is not obvious because the service quality may degrade for certain applications during run time. Further, non-predictable user's preferences for what is a good QoS, in the context of multiple applications with choices, adds the complexity [3]. Conversely, it is not enough to maximize QoS without considering the overall system benefits. Modeling benefits and QoS for MSAs is important to enable service providers offer the best TTSs with high societal benefits to users.

MSAs have been proposed as a potential approach for achieving TTSs that makes use of synergies between functionalities to improve system benefits [7]. The proposed model [7] did not take into account the varying QoS preferences between applications. Building on earlier work [7], we introduce the QoS dimension to study how performance based QoS may influence the system benefits. Studies show that service benefits have a relationship with the QoS [10] though this relationship has not been further investigated. There are models aimed at studying the performance quality of communication systems [5] and processing systems [11], [12]. Until now, no study found so far has addressed QoS explicitly in relation to benefits for multi-service applications in road-based HGV transport. Instead several studies have addressed QoS in relation to network resources for telecommunication systems with focus on satisfying service level agreements or comparing service offers between providers [2]. Models for measuring different quality aspects related to telematic services have been proposed [13], but they did not include the effect on benefits of such services.

In this work, QoS will refer to the system's performance quality which is assumed to characterize the end user's perception of quality. Unlike internet applications it is not clear how the QoS may be affected if several ITS applications are deployed on a common platform sharing several functionalities. Different applications will require different levels of QoS characteristics such as reliability, timeliness, completeness, costs and availability depending on the priority and goal for which such applications were designed. The impact of quality aspects to the benefits of a service have been summarized and categorized as alignment to reality in; time, space, content and the number of informed users [8]. The problem addressed in this study is to establish a benefits model that takes into consideration the QoS metric. Such a model will help service providers understand the benefits or losses associated to service quality. This study is an extension of a previous model (TTS benefits model) [7] to incorporate a quality based cost function. The model can then be solved as a resource allocation problem with given QoS parameters which can be varied to study the overall system benefits. The structure of the rest of this paper is as follows: section II establishes the relevance of the problem, section III takes a closer look at QoS and MSAs while section IV establishes a mathematical model of MSAs that takes into accounts system benefits. Section V present concluding remarks, followed by acknowledgement and references.

II. RELEVANCE OF THE STUDY

1. MOTIVATION

ITS applications for HGV transport are aimed at achieving several goals e.g. improving the utilization of different types of transport resources, minimizing the external effects of different transport activities etc. Therefore in a Multi-service architecture platform, it is to be expected that several applications sharing resources will operate to maximize different goals for which they were designed. Such resources could be communication network resources e.g. bandwidth, communication channels etc or computer processing resources e.g. memory, hard disk etc. For applications making common use of a given functionality and sharing resources, deadlock situations may arise during run time if the resources are insufficient or not carefully allocated. This will imply that certain applications will need to be associated priorities over others to manage such situations. Additionally, performance quality of the application may degrade when the demand for such resources are limited. Therefore there will be a need to prioritize which quality attributes be given preference when resources are limiting at runtime. In order to assess the benefits associated to applications in a MSA, potential tradeoffs from different applications need to be taken into consideration. Depending on the application emphasis could be on different quality attributes and because several applications share a platform, there are several tradeoffs that will need to be addressed. For instance applications oriented toward safety of life maybe may focus on time accuracy while applications oriented toward commercial benefits may focus on costs (figure 1) i.e.

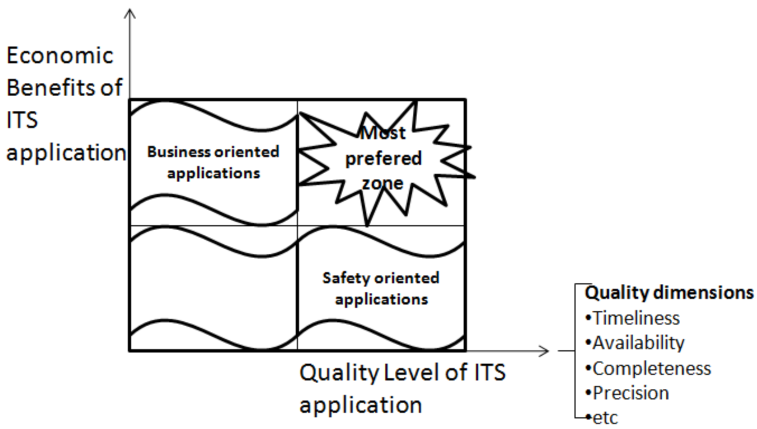

Figure 1: Concept illustration of QoS and ITS benefits

Different applications will impose different quality requirements on shared resources that will have an influence on the benefits of the entire system. Quality attributes such as availability, completeness, timeliness, precision etc set to different levels, with varying relative priorities for different applications will have an influence on the costs and hence benefits of various applications.

2. RELATED WORK

A survey carried out to investigate QoS attributes for general communication systems identifies the need for flexible and generic QoS models [1]. Based on the survey results [1] key factors for such models in a heterogeneous environment are the ability to define perceived QoS at the user interface level; how to relate this to underlying QoS supported within the underlying system, and how QoS aware interacting applications can adapt. The importance of such generic models could be to enable comparison of quality attributes between different applications. Of all the models that were studied in this survey [1] there was none that focused on how system benefits are related to various quality attributes. A related study has synthesized the profit consequences of service quality and the relationships with service quality and found out that the relationship between profit and service quality as an area within social sciences require further research [6]. For computer network resources, a study proposed a QoS approach based on analytic performance models in which computer systems can self adjust their parameters to constantly ensure that QoS requirements are satisfied [11]. The proposed model [11] measures the deviation of a given resource utilization from the maximum performance value and hence is generic enough to be applied to other application resources. Based on their approach [11], we proposed a similar measure of performance QoS for TTSs and incorporate this to the cost function of the proposed benefit model [7].

For TTSs, a knowledge-based system and architecture for the formalization of QoS characteristics and measurement methods, and for the collection, distribution and assessment of the QoS information has been addressed [2]. Their work [2], makes an attempt to develop an ontology for comparing QoS attributes for multiple TTSs but no attempts on how to model the relationship with the architecture benefits. To determine the right parameters for the QoS in transport telematic services, a study suggests the suitability of service accessibility, service operability, stability, achievability and network performance as relevant parameters that can be used to quantify QoS [13]. Even though their work [13] acknowledges the dependency between the level of service and the maintenance costs, the effects of such service levels on system benefits were never considered.

Work done on the management of web based content distribution in the form of telematic services shows that with increasing data volume and QoS demands, a thick client solution in which processes are distributed and executed at client stations could be better than a thin client solution where content data is distributed to users [4]. Even though their work [4] is focused on distributing web content, the results are indicative of the potential of MSAs to influence service quality. An illustration of how a layered scheme for QoS provision (in wired and wireless IP networks) for a user-domain multi-service architecture can be used as an experimental test bed, has not specifically studied the benefits of MSAs [15]. Benefits of different applications have been addressed following resource management approaches. For instance a QoS driven resource management for network computing that maximizes the total benefit provided to the applications is used to design the dynamic scheduling algorithms [14]. Abstracted benefit functions were used in this study [14] and a simulation model was used to study the performance of the proposed algorithm. A related study fulfilling the need for a generic QoS model identified above [1], addresses the QoS based resource management for multi-media applications, resulting to a proposed new analytical and generic resource management algebraic based model [10]. Application benefits functions and resource demand functions are used to represent the system configuration and to solve the resource demand problem [10]. The proposed model [10] did not provide an explicit modeling of benefits. However we found that the proposed generic model [10] was suitable for extending the benefit model in [7] so as to take into account the application priorities.

Relating QoS and benefits, a research project investigates the relationship between ITS service quality and benefits/costs, with the objective to determine the optimum service quality in four European service cases, identify levels of data quality providing optimal service quality and to give a recommendation for European guidelines for quality assurance of traffic data [8]. This paper differs from previous work [8], in that we focus on modeling how the benefits of a MSA may be affected by QoS and in particular the introduction of multiple services on a common platform. In a related study, MSAs have been suggested as a support to mobile IP applications, with end user enabled control of QoS in heterogeneous wireless networks [5]. Their work [5] was focused on web based applications and multimedia traffic with no explicit modeling of resulting benefits of such MSA with end-user enabled QoS control. We aim to establish a relationship between QoS and benefits using a quantitative based model.

It can be seen that, a number of studies have addressed QoS for communication and processing resources of various applications as a network resource utilization problem [1], [5], [10], [11] and also to characterize usage of networks in terms of effective bandwidth [9]. Few example studies were found with focus on transport telematic services [2],[13] and no study was found, as at now, with focus on services targeted toward road based HGV transport. Finally the study of MSA benefits and QoS in general has partially been touched [8], [5].

However QoS and benefits perspective used in [8] does not consider MSAs, while the MSA perspective in [5], has not considered benefits. This leads to the conclusion that QoS and benefits relationship for road based TTSs for HGVs have not been addressed up to this point in time. From the studies considered, MSAs have not been at the center of any study as a means for increasing overall system benefits, instead, quality issues for similar applications like web based contents have been addressed [4] and different approaches [10], [14] have been used to study different application benefits.

III. QoS AND MULTI-SERVICE ARCHITECTURES IN ITS

1. QoS ATTRIBUTES

Different types of service quality attributes can be considered such as timeliness, availability etc that can be used to differentiate MSA resource utilization at planning level. A detail description of these attributes has been provided in the QUANTIS project [8]. The following are some examples of important QoS attributes to consider for transport telematic MSAs.

a) Timeliness

This is a sensitive quality attribute especially for safety critical applications such as eCall, accident warning information, route guidance etc. The value of many services will largely depend on the ability of the system to respond in time.

b) Availability

The percentage of time the system is available or system uptime will determine it usage. End-user desired level may be different for different applications.

c) Completeness

This QoS attribute determines both the system geographic coverage and content of the information delivered to the end user. Different applications will offer different levels and content that may not necessarily meet user's desires.

d) Precision

The level of information precision is another important attribute that could vary significantly for different applications sharing resources e.g. accuracy of positioning location.

Table 1 is an example of how quality attributes and levels may vary for different applications.

TTSs	Timeliness (secs)	Availability	Completeness	Precision
XXL	<5	90%	89%	80%
RED	<10	90%	95%	90%
ITP	<2	95%	90%	92%
ODM	<2	97%	99%	95%
OSM	<1	99%	99%	95%

Table 1: Example of QoS levels for different attributes and applications

These quality attribute will generate demands on MSAs which need to be satisfied by employing resources provided by the architecture.

2. MULTI-SERVICE ARCHITECTURE RESOURCES

A MSA is a system architecture on which multiple applications can be deployed. Examples are seen in wired and wireless IP networks providing telecommunication services, [5], [15] and [16]. ITS service platforms have not yet developed to the same level as telecommunication service platforms as seen in projects such as COOPERS, HEAVYROUTE, and MOBIL IT etc. Such platforms would be based on different types of architecture concepts such as: Vehicle-to-Vehicle, centralized/decentralized data processing Vehicle-to-Vehicle-to-Infrastructure hybrid architecture etc. A common characteristic is that platforms are generally opened ended, flexible, scalable and expandable and they differ in the type of end user services anticipated and hence in the technologies. A MSA provides the ability to collect, communicate, process and share data and information using different types of technologies (tools & methods) that can be seen as architecture resources.

a) Data collection

Architecture concepts are different in the data collection technique employed which can be seen in two broad categories; intrusive and non-intrusive methods [17]. Intrusive data collection methods are based on technologies such as pneumatic road tubes, piezoelectric sensors, magnetic loops and non-intrusive data collection methods are based on remote observations such as manual counts, passive and active infra-red, passive magnetic, micro-wave radar etc. Thus MSAs will have different quality attributes requirements depending on the type of data method employed.

b) Data communication

Data communication for ITS architectures is mainly wireless communication with prioritized characteristics centered on real-time, autonomous, high reliability and handover features [18]. Anticipated communication systems are GPRS, GPS, and DSRC etc each of which offers different possibilities in terms of communication resources and costs e.g. the transmission data rate for ETC is 1024 kbps, Optical beacons (VICS) 1.024 Mbps (downlink) and 64 kbps (uplink), radio beacons (VICS) 64 kbps (GMSK) and 1 kHz (AM), and FM multiplex (VICS/D-DPS) 16kbps [18].

c) Data processing

Computer data processing may not be seen as a limitation, given today's computer processing capabilities, but because of real time demands that will be made by different applications running concurrently, the resulting processing capacity offered by each MSA will depend for instance on the computer processing network configuration.

d) Data and information sharing

A large amount of data and information (obtained by processing data) will be generated resulting to large data collection, communication and processing requirements that can be reduced through sharing e.g. it may be redundant for two HGVs to report road condition data if they are at the same location. This is because data and information sharing will affect communication capacity and processing capacity differently depending on the architecture concept used. The paradigm for reusable and modular software has been used to provide reusable components for interfacing data with the outside world with mechanisms for managing concurrent applications, and share derived streams across ITS applications [19].

IV. MATHEMATICAL MODELING

This study is about how to model the QoS degradation under conditions of shared resources and including costs associated to such degradation to determine the benefits for different potential MSAs. In this study resources, refer to communication (bandwidth and channel availability) and processing (memory usage) resources. If a system performs at maximum capacity, during run time, and the current work load is satisfied, the quality for which the system was designed can always be achieved. However, if the workload is more than the application can handle at run time then resources become limiting at that particular moment and the QoS will likely degrades. For telematic applications at pre-implementation, system behavior at run-time cannot be determined. However different resource allocation models (based on different MSAs) can provide understanding of how the QoS may vary in real time. A basic approach for estimating such QoS is to estimate the deviation from the expected maximum performance [11]. Thus we aim for a model that will maximize the benefits [7] such that the QoS requirements are satisfied. This means that instead of considering only services that are beneficial [7], idling system resources may lead to a penalty based on the extent to which the QoS requirement are satisfied. The modeling makes a number of assumptions:

- A MSA provides different resources based on which services can be implemented i.e. the type of resources and constraints determine the type TTSs achievable in a MSA.
- A desired (or required) QoS level can be set in advance to system implementation

We then consider the following sets:

S -TTSs targeted for freight transport e.g. road user charging, navigation, eCall etc

F -Functionalities required to achieve each service in S e.g. GNSS position etc

H -QoS Attributes for TTSs such as timeliness, availability, completeness, precision etc.

R -Resources such as processing, communication etc

A -MSA concepts; such as thin client, thick client etc, in terms of respective resource constraints e.g. communication and processing

Thus MSA (set A) can be seen as resources that are employed by different functionalities (set F) which results to a service (set S) that should meet the QoS specification (set H) as shown in the figure 2. For each QoS attribute, the desired QoS level with respect to system performance (will be referred to as maximum system performance in the model) is specified and compared to the QoS level achieved (will be referred to as current system performance in the model) under a given resource allocation model. Both the maximum and current system performance for each QoS dimension, are not necessarily the same for different services. In addition, transport policy requirements may lead some prioritization of the different QoS attributes.

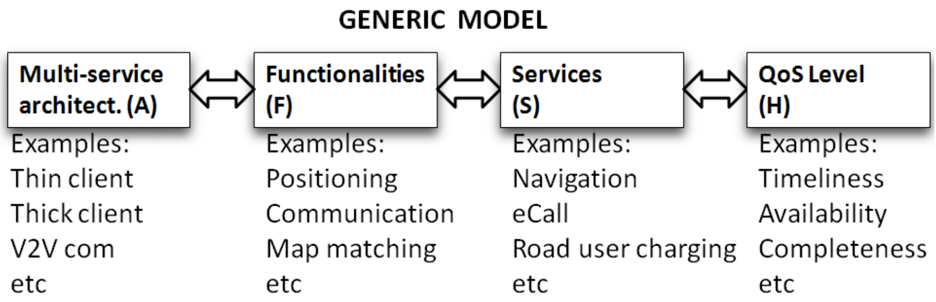

Figure 2: Diagram of a generic model showing how the sets A, F, S and H are related.

Thus, the following parameters and variables are defined:

PARA	**Definition**	**Assumptions**
B_i	$i \in S$ is the benefit of service (or application)	
B_{total}	Total benefits is a real number	
$\beta_i \geq 0$	$i \in S$ is the relative priority of service	Certain applications can be prioritized over others
$\tilde{A}_{qi} \geq 0$	$q \in H, i \in S$ is the resource demand constant	It is possible to estimate resource demand
$\tilde{f}_{qi}(x) \geq 0$	$q \in H, i \in S, x \in R$ is the resource demand function	
$W_{qir} \geq 0$	$q \in H, i \in S, r \in R$ is the priority of quality attribute for a shared resource	Priority is given some quality attributes relative to others
$C_j \geq 0$	$j \in F$ is the fix cost of a functionality resource	Start up costs
$C_{ir} \geq 0$	$i \in S, r \in R$ is the variable cost of each service for a given resource.	Use base or variable costs
$C_{qir} \geq 0$	$q \in H, i \in S, r \in R$, is the variable costs of a resource for a given service and quality level	Ratio of quality deviation equal increase in corresponding resource cost
$M_{iqmax} \geq 0$	$q \in H, i \in S$, is the maximum service quality (desired)	
$M_{iq} \geq 0$	$q \in H, i \in S$, is the current service quality (attained)	
$Z_t, t \in A$	1 if choice of architecture is considered, 0 otherwise.	
$A_{tr}, t \in A, r \in R$	1 whenever a resource is used by architecture, 0 otherwise.	
$\tilde{P}_r \geq 0, r \in R$	Cost of resource usage.	
V_i	$i \in S$ is the estimated societal value of a service	
VAR		
$X_i, binary$	$i \in S$ is 1 if service is selected, 0 otherwise	
$F_j, binary$	$j \in F$ is 1 if functionality is selected, 0 otherwise	
$\vartheta_{i\hat{i}} \geq 0, i, \hat{i} \in S, i$	1 when services i and $\hat{i}$ are selected, 0 otherwise.	
$\omega_t, t \in A,$	The total penalty cost for a given architecture.	

Table 2: Parameter (PARA) and variables definition of MSA benefits model

For multimedia applications the total benefits for multiple applications sharing multiple resources, based on WONJUN LEE (2001) model [10] is given by:

$$B_{total} = \sum_{i \in S} \beta_i * B_i(\sum_{i \in S, q \in H} \widetilde{A}_{qi} * \widetilde{f}_{qi}(x)) \quad (1)$$

Where B_i is the benefit function for application with resource demand function $\widetilde{A}_{qi} * \widetilde{f}_{qi}(x)$, $q \in H, i \in S, x \in R$ for resource x. This model can be extended to ITS service benefit model [7] where benefits have been estimated by

$$\widetilde{B} = \sum_{i \in S} V_i * x_i - \sum_{i \in S, r \in R} C_{ir} * x_i - \sum_{j \in F} C_j * f_j - \sum_{i \in S} A_{tr} * \widetilde{P}_r * Z_t - \sum_{i\hat{i} \in S, i \neq \hat{i}} \vartheta_{i\hat{i}} - \omega \quad (2)$$

From (1), if the application priority $\beta_i \geq 0, i \in S$ is taken into account, the societal value of the application $V_i \geq 0, i \in S$ and the costs function in the benefits equation (2) will change, thus:

$$\widetilde{\widetilde{B}} = \sum_{i \in S} \beta_i * V_i * x_i - \sum_{i \in S, r \in R} C_{ir} * x_i - \sum_{j \in F} C_j * f_j - \sum_{i \in S} A_{tr} * \widetilde{P}_r * Z_t - \sum_{i\hat{i} \in S, i \neq \hat{i}} \vartheta_{i\hat{i}} - \omega \quad (3)$$

From equation (1) benefits can be related to the QoS if we consider the definition of QoS with respect to system performance (as above) for given MSA resource allocation model, i.e. a measure of the deviation from the expected maximum performance [11]. Generalizing this assertion, for any given MSA resource and quality level, we obtain:

$$Q_{ir} = \sum_{q \in H, i \in S, r \in R} w_{qir} * \Delta Q_{qi} \quad , \quad \Delta Q_{qi} = \frac{M_{iq\max} - M_{iq}}{\max(M_{iq\max}, M_{iq})}, \; q \in H, i \in S \quad (4)$$

The costs function in equation (2) can now be redefined to include a usage based cost $C_{qir} \geq 0, q \in H, i \in S, r \in R$ that depends on the system's performance quality i.e. a deviation from maximum system performance suggested in equation (4) above, will lead to a corresponding fractional increase in the usage cost of the resource considered. Intuitively, the new costs function with a general QoS matrix can therefore be given by

$$C_{qir} = C_{ir} * (1 + \sum_{q \in H, r \in R} w_{qir} \Delta Q_{qi}), \quad i \in S \quad (5)$$

Where the second term will increase the use based cost if the quality of service degrades. This can be compared to the resource cost function defined by Y. Huang & B. Chao (2001) which is essentially the weighted sum of the ratio of current-to-maximum available resources [12]. Therefore the new benefit function with consideration for QoS can be given by

$$\widetilde{B}_{total} = \sum_{i \in S} \beta_i * V_i * x_i - \sum_{q \in H, i \in S, r \in R} C_{qir} * x_i - \sum_{j \in F} C_j * f_j - \sum_{i \in S} A_{tr} * \widetilde{P}_r * Z_t - \sum_{i\hat{i} \in S, i \neq \hat{i}} \vartheta_{i\hat{i}} - \omega \quad (6)$$

Two subjective measures in (6) are $\beta_i \geq 0$, $W_{qir} \geq 0 \quad q \in H, i \in S, r \in R$ which gives priority to certain applications, and quality attributes (for given resources), respectively. The function (6) estimates the benefits of different system applications with consideration for the QoS related to desired system performance.

V. CONCLUDING REMARKS AND FUTURE WORK

This work proposes a mathematical modeling that can be used to study how QoS characteristics may influence potential benefits of MSAs for road based freight TTSs. MSAs are considered to provide application resources like communication infrastructure and processing and QoS attributes create a demand on these resources (performance) leading to reduced MSA benefits, if such demands are not met. At the planning stage, resources employed by different applications (TTSs) are estimated in quantitative parameters and decision variables formulated into a mathematical model. Instances of the system behavior at run time can be analyzed with the model to estimate how the benefits of MSAs may be affected by QoS using a given resource allocation model. A system performance oriented QoS measure has been introduced providing a possibility to capture different quality attributes, desired performance levels, and even the possibility to introduce desired priorities between applications and quality attributes. Literature reviews within QoS and MSA benefits reveals that most of the studies carried out so far were eccentric to the subject matter investigated by our study.

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