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EVALUATION OF QOS IN UMTS BACKBONE NETWORK BY USING DIFFERENTIATED SERVICES

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A distinguishing feature of the Universal Mobile Telecommunications System (UMTS) is the support of different levels of quality of service (QoS) as required by subscribers and their applications. To provide QoS, the UMTS backbone network needs an efficient QoS mechanism to provide the demanded level of services on UMTS network. We implement a model to investigate end-to-end quality of service (QoS) provisioning approaches for UMTS networks in a DiffServ IP network environment. The effort was put on QoS classes mapping from DiffServ to UMTS, Access Control, buffering and scheduling optimization. The DiffServ Code Point was utilized in the E2E UMTS QoS provisioning to differentiate different types of traffic. We hybridized our work by applying Resource reservation protocol (RSVP) in routers and hosts. The main advantages and drawbacks are discussed. We found that our proposed model (hybridized model (DiffServ/RSVP)) improves the end-to-end delay and end-to-end variation compared with DiffServ model only, and it is superior to DiffServ regarding to throughput, utilization and packet loss ratio. The overall work guarantees the E2E QoS parameters of each service class, especially for real-time applications and improved the bandwidth utilization. Simulation results show that DiffServ can be an effective candidate for UMTS backbone bearer service.

KEYWORDS: *UMTS, DiffServ, End-to-End QoS, Scheduling, OPNET, QoS Metrics.*

1. INTRODUCTION

Third generation mobile systems like the Universal Mobile Telecommunication System (UMTS) are designed to provide a wide range of services and applications to the mobile user [1]. UMTS communication technology can transport both voice and Internet traffic. A main challenge for UMTS is to convey various types of traffic on the same medium while meeting their different QoS requirements. QoS is an end-to- end (E2E) concept that has to be satisfied through the inter-working of all the entities that the data is passing through. As a matter of fact, every different application has its own QoS contract and every contract has its own QoS parameters such as bandwidth, end to end delay, jitter, packet loss and throughput which in general could vary with continuity [2]. The development of end to end QoS algorithms was described in terms of mapping, access control, policing, buffering, and scheduling [3].

Two different internet QoS model have been proposed by the Internet Engineering Task Force (IETF), namely, integrated services (IntServ) and differentiated services (DiffServ). In IntServ network nodes classify incoming packets, and network resources are explicitly identified and reserved. In DiffServ, instead of explicit reservation, traffic is differentiated into a set of classes for scalability, and network nodes provide priority-based treatment according to these classes [4].

1.2 Differentiated Services

Differentiated services is a policy-based approach to QoS support in the internet, where traffic entering particular network is classified into different classes, and classes are assigned to different behavior aggregates [5] .DiffServ uses the DiffServ code point (DSCP) field in an IP packet header, which determines the service type of data traffic by specifying a per hop behavior (PHB) for that packet. Packet marked into the same PHB class experience similar forwarding behavior in the core nodes. PHBs are actually implemented by means of buffer management and packet scheduling mechanisms in the core nodes. For service differentiation for individual or aggregated flows ammeter measures the sending rate of a flows, and a market sets the DSCP fields of packets in the flow at the ages of the network. A dropper discards packets of different flows according to the DSCP fields and the current load with various dropping precedence polices in the core of the network.

2. MAPPING FROM DIFFSERV CODE POINT TO UMTS QOS CLASSES

A vertical mapping is defined between the UMTS QoS classes and the IP DiffServ classes as described in Table (1). The Expedited Forwarding Per Hop Behavior (EF PHB), which is characterized by low delay, low jitter, and low packet loss. The specified arrival rate will be dropped in advance. Traffic in the conversational class like VoIP matches this DiffServ class very well: the source traffic rate from a voice session is highly predictable, highly delay sensitive, but relatively loss insensitive. AF PHB can support the streaming class, since that class has higher delay constraint than the interactive class, but less constraint than the conversational class.

Table 1 Mapping UMTS classes onto DiffServ classes

UMTS QoS Classes	DiffServ Classes	Reason
Conversation	EF	As it is requires low delay and jitter and PF class guarantees a mini-mum service level.
Streaming	AF/Class 4	As it is required low variation of delay.
Interactive	AF/Class 3	As it requires low delay but not as low as in conversation class.
Background	AF/Class 2,3,or best effort	As there is no specific requirements for this class except reliability.

3. QUEUING DIFFERENTIATION

The design of scheduling algorithms for mobile communication networks is especially challenging given the highly variable link error rates and capacities, and the changing mobile station connectivity typically encountered in such networks [6].

The Weighted Fair Queuing (WFQ) scheme is based on the Generalized Processor Sharing (GPS) framework. In the GPS framework, backlogged sessions are serviced simultaneously in proportion to their service shares. Using the GPS framework it is possible to bind the end-to-end delay of a connection through the network irrespective of the cell/packet arrival rate of other connections. GPS systems are also fair in distributing the bandwidth among different connections.

WFQ algorithms are work conserving algorithms that are fair in distributing link bandwidth among connections. Any unused bandwidth is distributed according to the weights of the active connections. Several improvements to the basic concept of WFQ have been reported, The WFQ algorithms distribute bandwidth in relation to the weights assigned to different connections, and however, they do not guarantee TDM type bandwidth allocation for connections that require minimum bandwidth guarantees. Changing the virtual time to actual time allows WFQ algorithms to become non-work conserving and hence able to guarantee TDM type minimum bandwidth. A combination of WFQ algorithms that provide sharing of bandwidth on the weights assigned to a connection and minimum bandwidth guarantees is essential to support of VBR and DiffServ AF services.

4. SIMULATION AND EVALUATION

The investigated E2E QoS scenario and simulation experiments are described in this section, where all the QoS model in the previous sections are applied. The optimization target in the simulation is to achieve E2E delay, better E2E delay variation and link bandwidth utilization. So the Key Performance Indicators (KPIs) are:

- E2E delay.

- E2E delay variation.
- Bandwidth utilization.
- Packet loss

This paper focuses on two important scenarios:

- The first scenario investigates end-to-end quality of service (QoS) provisioning approaches for UMTS networks in a DiffServ IP network environment. We mapped from Diffserv to UMTS and measured the E2E delay and E2E delay variation.
- The second scenario hybridize between the two models (Diffserv and RSVP) and show the advantages and drawbacks from the hybridize techniques.

5. MODEL IMPLEMENTATION

We implement a model to evaluate end to end service quality, throughput, end-to-end delay and delay variation through the radio access network and core packet network.

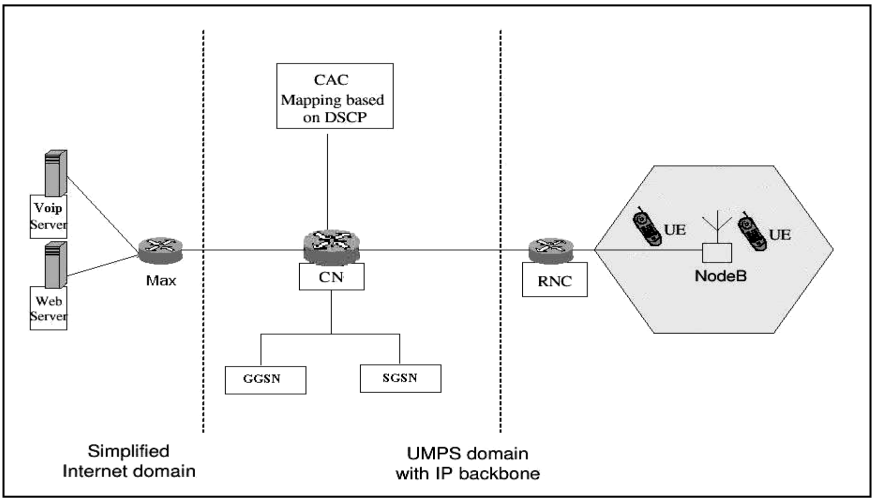

Figure 1 E2E QoS scenario

5.1 Simulation Scenario

A DiffServ router consists of some classification, traffic conditioning and queuing blocks, such as a classifier, meter, marker, dropper, counter, multiplexer, queues, and scheduler. The focus of the discussion is on four components: scheduler, algorithmic dropper, meter, and classifier. The other router’s components such as: counter, marker, and multiplexer have not been discussed in our model because of their inherent structural simplicity.

We consider two traffic groups, each corresponding to one of the four UMTS traffic classes, that is, the traffic flows of each of these classes are aggregated into two groups, each represented by one DiffServ PHB, resulting in two groups of traffic aggregates in the core network. Group one is an aggregate of traffic with a conversational class, having high delay and jitter sensitivity. Group two is an aggregate of traffic with an interactive class see Table 2.

Table 2 QoS mapping table

Groups	G1	G2
PHB	EF	AF2

One of the basic tools of packet differentiation in networks is the scheduling element since its performance has the highest impact on the level of service a packet receives. There are a large number of different scheduling schemes present, which has some advantages and some disadvantages. We used WFQ scheduling because it is suitable for DiffServ network and employed RED (Random early Detection) as a Dropper Elements to avoid congestion.

As shown in Figure (1), there are two application servers located in the Internet domain, and each one of them supplies one type of application: Voice and web service via HTTP,. The IP data packets are sent to the edge router. The edge router marks IP packets with different DSCP according to their application type. The core network consists of an SGSN, a core node and a GGSN. The SGSN and GGSN nodes also work as DiffServ edge routers. Therefore, they do IP encapsulation and perform the mapping function. The core node only applies the PHB associated with the codepoint marked in each packet header.

The GGSN normally uses the GPRS Tunneling Protocol (GTP) and an encapsulation for the UMTS IP transport, but this is simplified in the simulator (no GTP). Application parameter settings are shown in Table 3.

Table 3 Traffic parameters in Simulation

HTTP Parameter	
HTTP Specification	HTTP 1.1
Pages Inter arrival time	exponential (60)
Server Selection	
Entail repeat probabilities	Brows
pages per server	exponential (100)
Type of Service	Excellent effort
Voice Parameter	
Silence length	exponential (.65)
Take spurt length	exponential (5)
Voice frames per packets	1
Type of Service	Interactive voice (6)

6. RESULTS AND DISCUSSION

A) The First Scenario

The first scenario investigates end-to-end quality of service (QoS) provisioning approaches for UMTS networks in a DiffServ IP network environment. We mapped from Diffserv to UMTS and measured the E2E delay and E2E delay variation.

The cumulative distribution function of end-to-end delay for voice is shown in Figure(2) for both Qos support framework (DiffServ) and without it. As can be seen in this figure, the distribution function when employing the DiffServ framework shows a uniform increasing function for delay from 75 ms up to 89 ms. While without this framework (DiffServ), the distribution function increases for delay from 77 ms up to 91 ms.

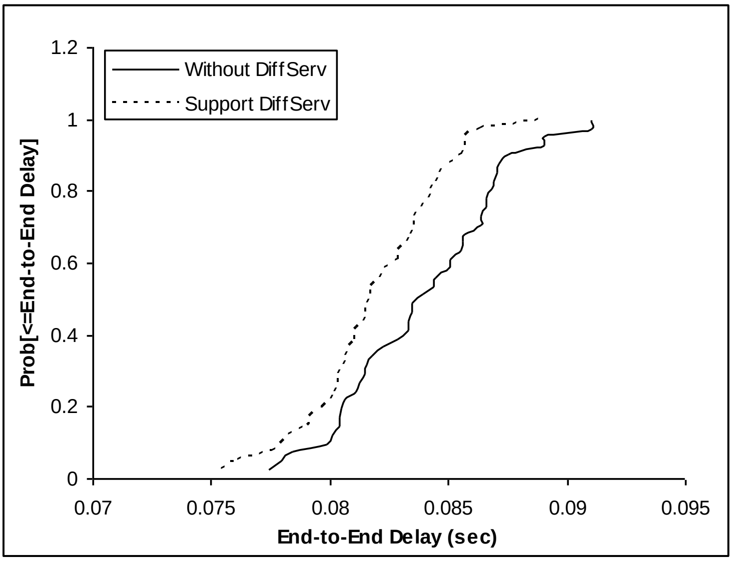

Figure 2 Cumulative Distribution Function for end-to-end Delay for voice application

The data in Figure (2) are well fitted to the following sigmoidal equations for support framework (DiffServ) and without using it respectively:

$$Y = \frac{-0.995}{1 + e^{\frac{(X - 0.0819)}{1.7x10^{-3}}}} + 1.0$$

$$Y = \frac{-1.02}{1 + e^{\frac{(X - 0.837)}{2.29x10^{-3}}}} + 1.0$$

Where Y is the cumulative distributions function and X is the delay in seconds.

On the other hand, Figure (3) represents the cumulative distribution function of end-to-end delay for web application. Under the QoS support framework (DiffServ), the distribution function shows a linear increase for delay from 88 ms and up to 1321 ms. While without DiffServ, the delay distribution function shows a linear increase for delay from 88 ms up to 1485 ms. From the Figure we can conclude that when using DiffServ 57% of the delays are below 860 ms, while without this framework 57% it are below 951 ms. Accordingly, DiffServ decrease the delay for web application as long as delay is less than gives less delay for web application which gives better performance for web application in this type of networks.

The data in Figure (3) is fitted with the following linear equations when using DiffServ and when not using it respectively:

$$Y = 0.742X - 0.078$$

$$Y = 0.85X - 0.206$$

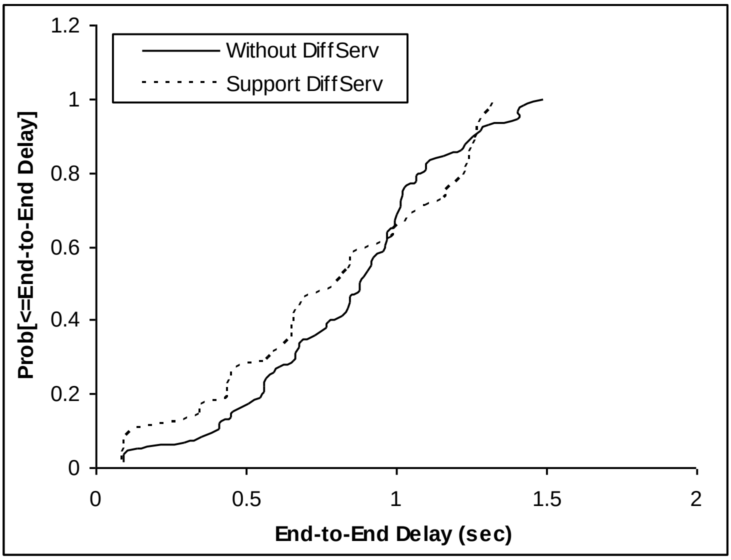

Figure 3 Distribution function of end-to-end delay for web application

As it is known that voice traffic is very sensitive to delay and delay variation. Figure (4) shows the cumulative distribution function for the delay variation for the real time application (voice). As shown in Figure (4), 90% of the delay variation is below $109x10^{-3}$ ms which is low value compared with that achieved without DiffServ where 90% of the delay variation below $120x10^{-3}$ ms. This confirm that DiffServ enhance the performance of the network by reducing the delay variation.

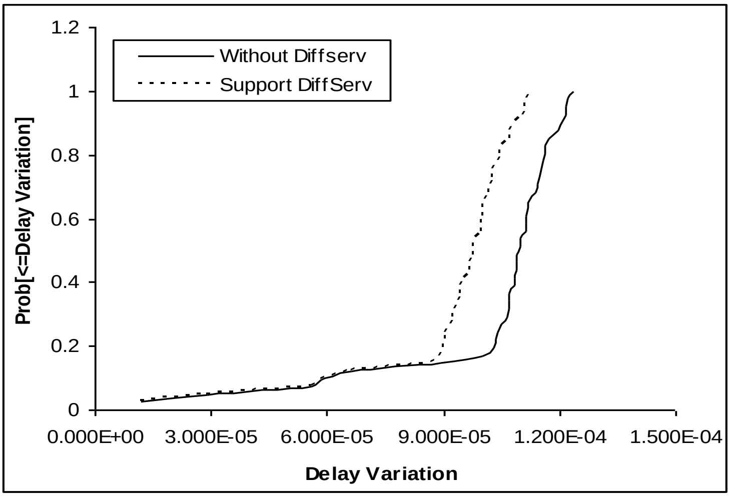

Figure 4 Cumulative distributions function for delay variation
For voice application

The data in Figure (4) are well fitted to the following sigmoidal equations for support framework (DiffServ) and without using it respectively

$$Y = \frac{-0.925}{1+e^{\frac{(X-9.87x10^{-5})}{4.82x10^{-6}}}} + 1.0$$

$$Y = \frac{-0.918}{1+e^{\frac{(X-1.11x10^{-4})}{4.18x10^{-6}}}} + 1.0$$

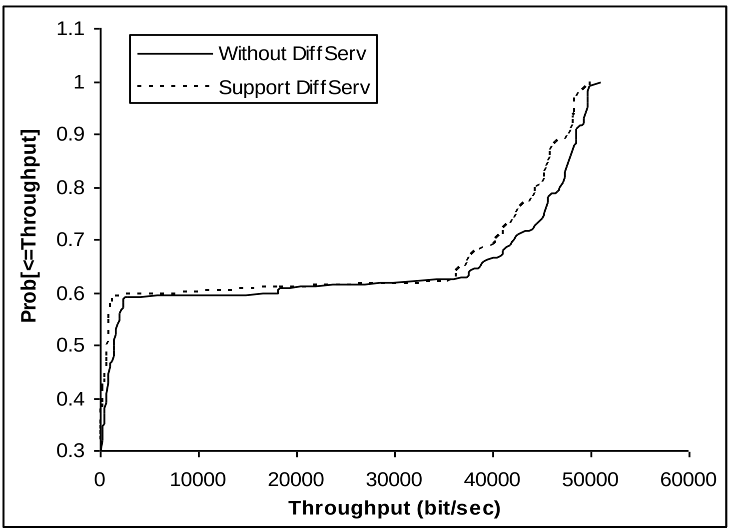

Figure 5 CDF for point-to-point throughput

Figure (5) shows the cumulative distribution function for point-to-point throughput when using DiffServ and without using it. In this figure we can see that the DiffServ did not make a significant effect.

The data in Figure (5) can be represented by the following exponential equations for support framework (DiffServ) and without using it respectively:

$$Y = 0.447 + 0.0114e^{\left(\frac{X}{12.9x10^3}\right)}$$

$$Y = 0.465 + 0.006e^{\left(\frac{X}{11.6x10^3}\right)}$$

Also, Figure (6) show the effect of using DiffServ on the average point-to-point utilization. Again, from this figure, we can conclude that DiffServ does not have a noticeable effect on utilization.

Again the data in Figure (6) are fitted to the following equations for DiffServ and without it respectively:

$$Y = 0.442 + 0.012e^{\left(\frac{X}{0.85}\right)}$$

$$Y = 0.457 + 0.008e^{\left(\frac{X}{0.785}\right)}$$

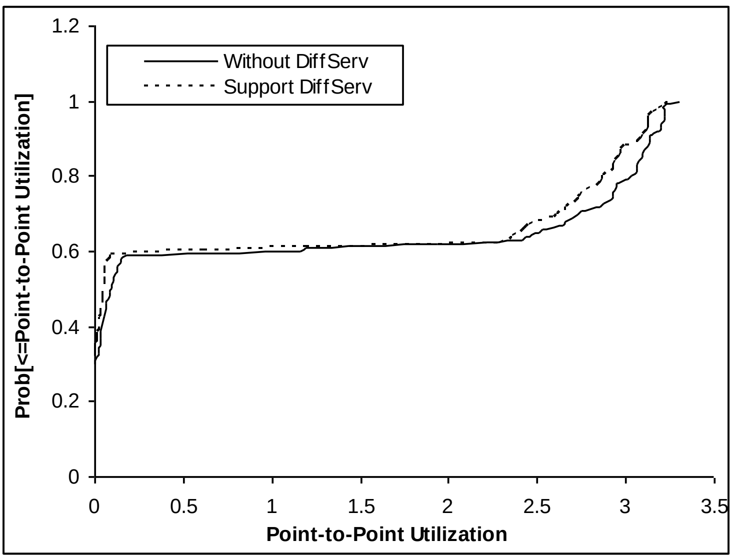

Figure 6 CDF for point-to-point utilization

We also investigate the effect of DiffServ framework on the packet loss ratio. The results are shown in Figure (7), where it is clear that 98.5% of the packet loss ratio are below than 0.0055 when using DiffServ, while without it, 98.5% of the packet ratio is below than 0.150. This result shows that the DiffServ framework enhanced framework enhanced service of the network by reducing the packet loss ratio.

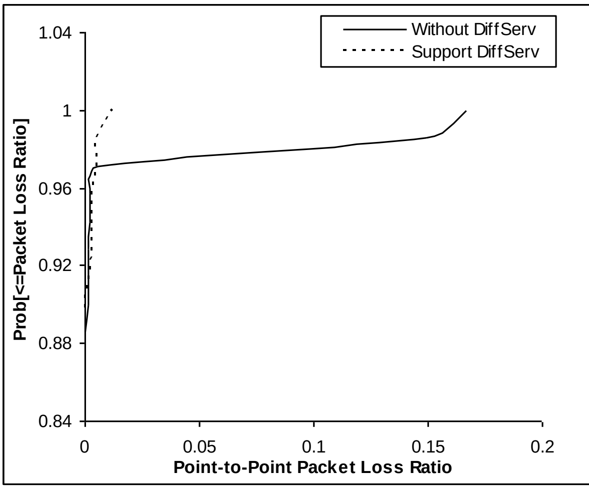

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Figure 7 CDF for point-to-point packet loss ratio

B) The Second Scenario

The second scenario is hybridization between the two models (DiffServ and RSVP).

RSVP

RSVP is a signaling protocol that allows applications to reserve resources in the Internet (link bandwidth, buffer space, and so on). Once a reservation is made, the router decides what scheduling and policing it needs to put in place to support the reservation (e.g. WFQ and token buckets). RSVP does not specify how the network provides the reservation; it only allows applications to make the reservations.

The cumulative distribution function of end-to-end delay for voice is represented on Figure (8), providing the acceptable end-to-end delay for voice. From this figure we can see that using the QoS support framework (DiffServ/RSVP) show a slight decrease in the delay compared with the framework DiffServ.

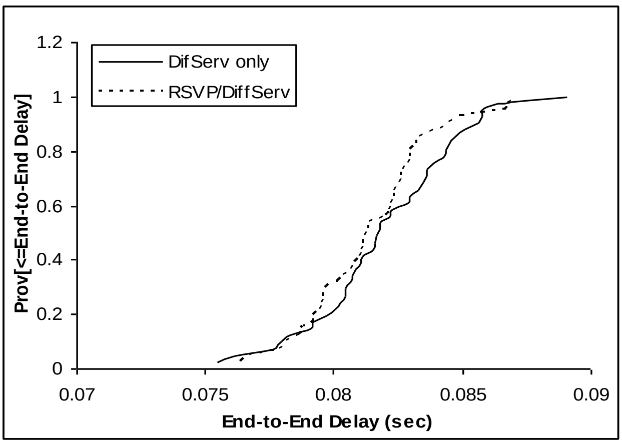

Figure 8 Cumulative distributions function for end-to-end delay for voice application

Such a curve can be represented by the following equations for DiffServ and DiffServ/RSVP respectively:

$$Y = \frac{-0.995}{1+e^{\frac{(X-0.0819)}{1.7x10^{-3}}}} + 1.0$$

$$Y = \frac{-0.985}{1+e^{\frac{(X-0.0814)}{1.4x10^{-3}}}} + 1.0$$

As previously stated, voice traffic is very sensitive to delay and delay variation, so we investigate the cumulative distribution function for the delay variation for the real time application (voice) which is represented in Figure (9).

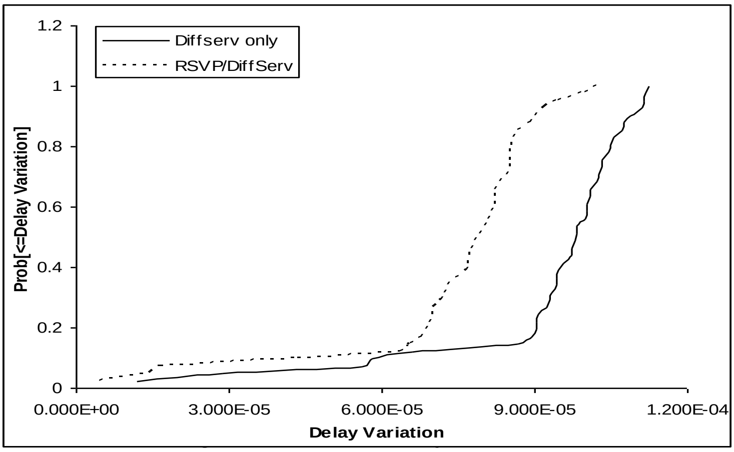

Figure 6 CDF for dealy variation

In this figure, for the Qos support framework (DiffServ/RSVP), 80% of delay variation is below *86x10*$^{-3}$ *ms* while for DiffServ only 80% of delay variation is below *105x10*$^{-3}$ *ms*. This means that the hybridized model (DiffServ/RSVP) gives a significant enhancement in the delay compared with DiffServ alone.

The equations of these cures for DiffSev and DiffServ/RSVP respectively are:

$$Y = \frac{-0.925}{1+e^{\frac{(X-9.87x10^{-5})}{4.82x10^{-6}}}} + 1.0$$

$$Y = \frac{-0.925}{1+e^{\frac{(X-7.96x10^{-5})}{5.41x10^{-6}}}} + 1.0$$

Figure (10) shows the cumulative distribution function for point-to-point throughput for DiffServ and (DiffServ/RSVP) hybridization.

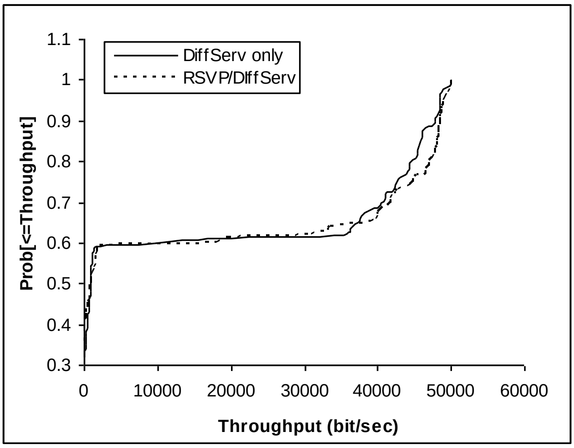

Figure 10 CDF for point-to-point throughput

In this figure, the DiffServ/RSVP support shows a slight increase in the throughput in the range of $37x10^3$ – $50x10^3$ bit/sec, at other values of throughput. DiffServ didn't show a significant effect.

We can conclude that the hybridized DiffServ/REVP support affect the throughput significantly.

This data are fitted to following equations for DiffServ and (DiffServ/RSVP) respectively:

$$Y = 0.494 + 0.0035e^{\left(\frac{X}{10.25x10^3}\right)}$$

Finally the effect of the hybridized model (DiffServ/RSVP) on the utilization is studied and the results are represented in Figure (11).

For DiffServ only 80% of utilization is below 2.9, while when using (DiffServ/RSVP) 90% of utilization is below 3.1. This means that the hybridized model gives only a very small effect to the utilization.

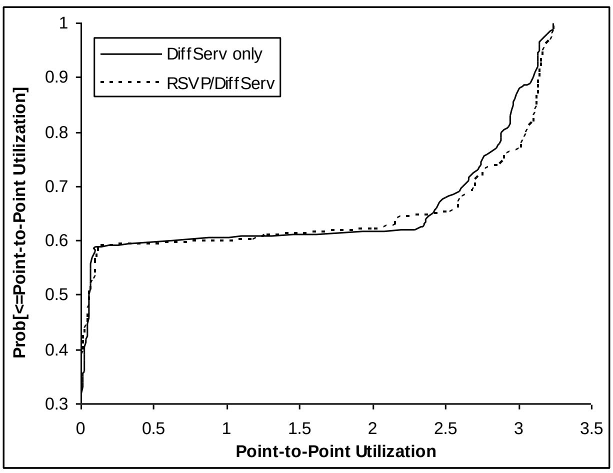

Figure 11 CDF for point-to-point utilization

The equations of these curves are given bellow for DiffServ and DiffServ/ RSVP respectively.

$$Y = 0.442 + 0.012e^{\left(\frac{X}{0.85}\right)}$$

$$Y = 0.489 + 0.004e^{\left(\frac{X}{0.68}\right)}$$

The effect of hybridized DiffServ/RSVP on the packet loss is also examined, as shown in Figure 12.

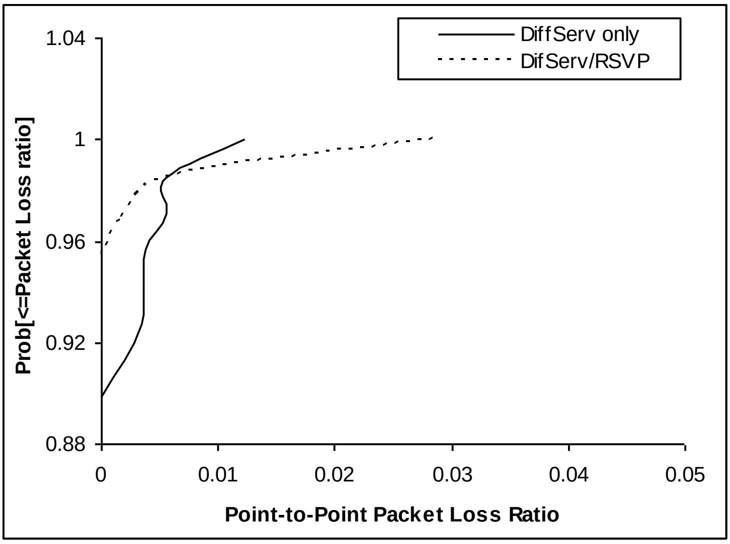

Figure 12 CDF for point-to-point packet loss ratio

Here, 97% of the packet loss is below than 0.0018 when using DiffServ/RSVP, while with DiffServ only, 97% of the packet ratio is below than 0.0055. This result shows that, compared with DiffServ support, the DiffServ/RSVP reduced the packet loss ratio.

From the first and second scenarios, we can conclude the following:

- Differentiated Services model improves the end-to-end delay and end-to-end delay variation especially for real time applications.
- Although Differentiated Services model has the advantage of being scalable model (focusing on traffic aggregated with similar service requirements), but it also has some drawbacks, i.e. no signaling protocol to check the availability of resources E2E.
- The hybridized (DiffServ/RSVP) model is a scalable model and improves the delay and delay variation for voice compared with DiffServ model only and gives a significant improvement regarding throughput, packet utilization and packet loss.
- The mechanisms are very simple to implement and do not require additional signaling.

7. CONCLUSION AND FUTURE RESEARCH

This paper focuses on investigating an optimized UMTS Quality of Service provisioning strategy in an E2E scenario to supply QoS guarantees as well as to improve system performance. We have presented a basic model for deploying DiffServ in UMTS backbone networks to support the core network's QoS requirements. The study addressed two implementation related issues: the structure of a DiffServ-aware UMTS backbone router and QoS mapping related issues. The router utilizes the DiffServ functional elements with novel algorithms to build two datapaths for two different PHBs. The scheduling block is based on WFQ service discipline that is Suitable for DiffServ network. A simulation model of the backbone network has been used to evaluate the overall performance of the system when treating a packet according to its PHB group, mapped from its UMTS traffic class. We have presented simulation results on the end-to-end delay, throughput and end-to end delay variation to show the effectiveness of the prototype in providing service differentiation in the backbone network. Also, we found that the hybridized model (DiffServ/RSVP) improves the end-to-end delay and end-to-end variation compared with DiffServ model only, also (DiffSev/RSVP) is superior to DiffServ regarding the throughput and utilization

Future analysis will include other traffic models for upcoming new applications in UMTS networks.

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تقيم جـودة الخدمـة في نظـام الاتصـالات العالمــي باستعمـال الخدمـات الممــيزة

أن الميـــزة المميـــزة لنظـــامِ الاتصـــالات النقَّـــالِ العـــالميِ هـــو دعـــمُ المســـتويات المختلفـــةِ لنوعيـــةِ الخدمـــةِ والجـــودة كمـــا هـــو مطلـــوب مِـــن قِبـــل المشـــتركين وتطبيقـــاتِهم. و لتَزويـــد تلـــك الشـــبكة بهـــذه الجـــودة والخدمـــة المطلوبـــة نحتـــاج إلـــى آليـــة فعالـــة لتَزويـــد المســـتوى المَطلوب للخدمات في هذا النوع من الشبكات.

وقـــد قمنـــا فـــي هـــذا العمـــل – عـــن طريـــق نمـــوذج لمحكـــاه شـــبكات النظـــام العـــالمي للاتصـــالات – بدراســـة جـــودة الخدمـــة فـــي هـــذه الشـــبكات تحـــت بيئـــة الخـــدمات المميـــزة وكـــان تركيـــز عملنـــا علـــي وضـــع أنـــواع الجـــودة والتخـــزين والـــتحكم والجدولـــة علـــي أصـــناف مختلفـــة مـــن التطبيقـــات وقمنـــا بتهجـــين هـــذه البيئـــة مـــع نظـــام حجـــز المصـــدر فـــي الشـــبكة من حيث المسارات والمضيفين لمعرفة الفوائد والعوائق الرئيسية.

وقـــد وجـــدنا أن نموذجنـــا المقتـــرح المهجـــن قـــد قـــام بتحســـين كـــل مـــن زمـــن تـــأخير البيانـــات ،اخـــتلاف التـــأخير المتلاصـــق ، كميـــة البيانـــات التـــي يـــتم تداولها.ومعـــدل فقـــد البيانـــات بالمقارنة بنموذج الخدمات المختلفة (بدون تهجين).

بشـــكل عـــام يمكـــن القـــول بـــأن نتائجنـــا عـــن المحاكـــاة قـــد أظهـــرت أن نظـــام الخـــدمات المختلفة يصلح كنظام فعال لخدمات نظام الاتصالات النقال العالمي.