Architecture of Next Generation Network with Information Sharing

Gufang Tu, *Senior Memberr, IEEE,* Can Zhang, Yi Zhang, Derong Liu, *Fellow, IEEE*

***Abstract*—In this article we present the architecture of the next generation network with information sharing by setting up access network protocol stacks and IP QoS over MPLS model to realize the inter-operation of heterogeneous networks, which maybe run by different operators or in various technology domains. This networking architecture is all-IP-based. It merges various types of networks, wired or wireless, fixed or mobile, backbone, local area or personal, by adding on an overlay network layer built on top of existing networks. It is referred to as knowledge management layer. Knowledge management layer is the peer - to - peer networking facility consisting of new hardware and software residing on top of IP edge router or media Gateway nodes. The proposed architecture provides all-IP-based information sharing. It enhances QoS support, security and mobility, and network composition by managing and controlling the network state, behavior and resources in an optimized manner. Here in this article, we give an overview of the various network architecture, the evolution of the network architecture toward all-IP-based mobility networks with information sharing, and then introduce the NGN architecture, its main features and access network protocol stack, which enables the NGN networks concept. Scalable coding and QoS control in the NGN, will be presented in more detail.**

I. INTRODUCTION

The Next Generation Network (called NGN for short) with information sharing is based on all-IP-based mobile network that merges fixed, mobile, wired, wireless network, and increases the overlay network layer built on top of existing networks. The overlay network layer is the peer - to - peer network deployed new software and new hardware on top of some IP edge router or media Gateway nodes. It can realize information sharing and cooperative working and the communication supposition of anytime, anywhere and anyone. The traditional telecom network always makes use of telephone network that is composed of SPC (Stored Program Control) exchangers based on circuit switching, whereas the NGN telecom network is based on packet switching; the computer network is the Internet based on IPV4, whereas the NGN Internet is based on wideband IPV6; the mobile communication, nowadays, takes GSM and 2.5G as the typical networks, whereas the NGN mobile communication is the third generation mobile communication system based on 3G and 4G; the broadcast television network is the analogous network with broadcast mode or circuit switching, whereas the NGN broadcast network is the digital network with broadcast mode or packet switching. On account of the historical reasons, the traditional network has many kinds, such as: telephone network, integrated service digital network, local area network, the third generation mobile communication system, WLAN, WATM, satellite communication system, virtual private network etc. The different networks bear different services (including voice, data, video, image, fax etc.) and have their own communication platform for bearing and multiple access technologies. In today's various networks technologies, the trends in networking technology very much point to dominance of Internet technology with all its flavors. IP is the key technology to enable the exchange of data across various networks. There is, however, an increasing divergence in the network control layer: different control environments are established to facilitate services like virtual private networks, quality of service (QoS), mobility, security, multicast, network address translation, and so on. For a multitude of services, data might still be handled by uniform Internet networking [1], with the increase of the ratio of IP data service to telecom service, the architecture of network is taking the essential changes. The network designed for voice and narrowband must match in cross layers (protocol and network, channel and modulation) and optimize (joint source and channel coding, QoS control, horizontal and vertical handover) and normalize network behavior (Small world, Scale Free). And, it must modulate and control network resource and behavior. We aid to increases the overlay network layer built on top of existing networks, is called knowledge management layer. The overlay network layer is peer - to - peer networks deployed new software and new hardware on top of IP edge router or media Gateway. nodes in existing networks, to realize the information sharing and cooperation of heterogeneous networks. This new view of network architecture has the effective management of information sharing, cooperative working, all - IP-based mobility security, and network composition by matching and control of the network state, behavior, and resource. Through these measures, the network can adapt to the transmission demands of the stream medium with wide band and All-IP, and make use of the IP frames to bear the stream medium

Guofang Tu is with the School of Information Science and Engineering Graduate School of the Chinese Academy of Science, P. O. Box 5488 Beijing 100049, P. R. China.(corresponding author to e-mail: gft@gucas.ac.cn).

Can Zhang, Yi Zhang is with the School of Information Science and Engineering Graduate School of the Chinese Academy of Science, P. O. Box 5488 Beijing 100049, P. R. China.

Derong Liu, Department of Electrical and Computer Engineering, University of Illinois at Chicago (corresponding author to e-mail: dliu@ece.uic.edu)

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services of voice, data, image, video etc. So, it substitutes the mode that voice bears data and realizes the reliable transmission of the stream medium of voice, data, video etc in based on all-IP-based mobile network.

The organization of the paper is as follows. In section II, we give overviews of the evolution of NGN architecture, as such the Internet architecture, the GSM /GPRS network evolution toward a UMTS all – IP architecture, the WLAN/3G integration architecture. Section III gives architecture of the NGN with information sharing. Section IV gives access network protocol stacks and IP QoS over MPLS model in the NGN. Scalable coding and QoS control in section V and simulation results and discussions in section VI. In section VII, conclusions are drawn.

II. The Volution of The NGN Architcture

In the section, we give overviews of the evolution of NGN architecture, and the evolution of the network architecture toward all-IP-based mobility networks with information sharing.

A. The Internet Architecture

Research in the Internet community on future network architectures is mainly influenced by the discovered deficiencies of the current Internet. The Internet architecture evolved during the research phase, and it has continued to evolve [2]:

- The most important change during the 1974 –1980 research period was the separation of TCP into a network layer (IP) and transport layer (TCP), in version 4 of the protocols.
- Several important features were added to the architecture during the early 1980s, especially sub-netting, autonomous systems, and the domain name system (DNS). All of these changes reflecting an increasing understanding and respect for the issues of scale, imposed hierarchical design on the architecture.
- IP multicasting added logical addressing and multi – destination delivery fundamental parts of the architecture.
- Congestion control using packet loss as a congestion signal and additive increase multiplicative decrease algorithm at the end systems was added in the late 1980s in response to congestion collapse events.
- Extensions to technical design of the Internet have been developed are being developed in the IETF at increasing rate in the late 1900s. Examples include IP Security, mobile IP, Network Address Translator (NAT) devices, Quality of Service (QoS), label switching, VPNs, firewalls, routing, and horizontal and vertical handover.

We believe that certain of these evolutions were created with some architectural sensitivity [3]. The motivation for reconsidering the design of the Internet architecture is its current widespread presence and its impact on social, economic, and political aspects [4,5]. Efforts are made to define of a common set of architecture principles and tenets to guide the development of a new Internet architecture [6].

B. The GSM /GPRS Network Evolution Toward A UMTS All–IP Architecture

Current Global System for Mobile Communications / General Packet Radio Service (GSM/GPRS) Services (voice and circuit switched data) are supported via the base station subsystem (BSS) and network subsystem (NSS)[7]. The BSS consists of the base transceiver station (BTS) that handles the radio physical layer and the base station controller (BSC) that deals with radio resource management and handover. The NSS for circuit switched services consists of the mobile switching center (MSC), the visitor location register (VLR) integrated in the MSC, and the home location register (HLR). GPRS provides packet switched services over the GSM radio.

Universal Mobile Telecommunications System (UMTS) is the chosen evolution for all GSM networks. The UMTS consists of UMTS terrestrial radio access network (UTRAN) and UMTS core network connected over a standard interface. UTRAN composed of node B and a radio network controller (RNC). Node B is functionally similar to the GSM BTC, and RNC is similar to the GSM BSC. UMTS core network equivalent to the GSM/GPRS NSS.

As described earlier, UMTS is based on a new radio technology having a big impact on the UTRAN. The UTRAN consists of several possibly interconnected radio network subsystems (RNSs) [7]. An RNS contains one RUN and at least one node B. The RNC is in charge of the overall control of logical resources provided by the node Bs. RNCs can be interconnected in the UTRAN via the Iur interface.

At the end of 1999, evolution toward a UMTS all IP architecture started in 3GPP. This evolution was driven by two objectives:

- Independence of the transport and control application up to the mobile terminal
- Operation and maintenance optimization for the access network

This evolution has an impact on different parts of network. Three main evolution: a control plane part (MSC server) and a user plane part (media gateway) are separated; addition of an IP – based multimedia subsystem (IMS) ; extensions to IP transport technology within the UTRAN, as an alternative to the ATM – based UTRAN.

It is important to stress that these evolutions are independent of each other and can also be deployed in a fully independent way.

C. The WLAN/3G Integration Architecture

The recent evolution and successful deployment of wireless local area networks (WLAN) worldwide has yield a demand to integrate them with third generation (3G) mobile networks, such as GSM/GPRS/UMTS, and CDMA 2000. The key goal of this integration is develop heterogeneous mobile data networks capable of supporting ubiquitous data services with very high data rates in hotspots. A.K.Salkintzis present a general WLAND/3G integration architecture in which a WLAN can be shared by one or more 3G networks [8].

III. Architecture of The NGN With Information Sharing

The next generation network aim to enable the information sharing and inter-operation of heterogeneous networks, which maybe run by different operators or in various technology domains. We aim to provide architecture of the NGN with information sharing (as is shown in figure 1). This architecture is all-IP-based. It merges various types of networks, wired or wireless, fixed or mobile, backbone, local area or personal, by adding on an overlay network layer built on top of existing networks. It is referred to as knowledge management layer. Knowledge management layer is the peer - to - peer networking facility consisting of new hardware and software residing on top of IP edge router or media Gateway nodes. The proposed architecture can realize the information sharing and inter-operative working, integration of heterogeneous networks. It enhances QoS support, security and mobility, and network composition by managing and controlling the network state, behavior and resources in an optimized manner. The key requirements identified by the NGN are:

- Support for information sharing and inter-operation
- Efficient support for mobility and security
- Support for seamless service provision
- Support for diversified radio accesses
- Open interfaces to allow external application providers to use the NGN communication infrastructure.
- Support for horizontal handover and vertical handover

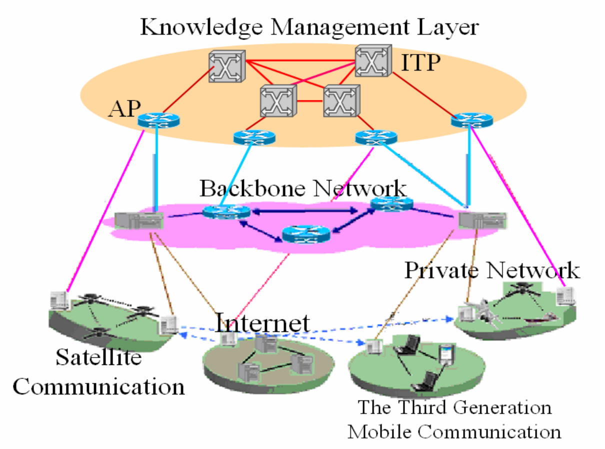

Fig. 1. Architecture Of The NGN with Information Sharing.

There are two kinds of accessing point in the knowledge management layer of the architecture of the NGN:

- Access Point (it is called AP for short)

AP is the nod of message handling and the extreme point of message transmission. And it is actually a part of edge router and multimedia gateway in the public network.

- Information Transition Point (it is called ITP for short)

ITP is the transfer point of the message transmission in the knowledge management layer. It transfers the message from one link to the other. And, it can be a part of edge router and multimedia gateway. Also, ITP can be deployed some new software and new hardware on top of IP edge routers or media Gateway nodes in existing networks. AP and ITP are connected by the signaling link to set up the knowledge management layer. This network adapts to the merging of network to realize the effective management and control for the NGN.

IV. Access Networks Protocol Stack Architecture And IP QoS Over MPLS Model In The NGN

A. Access Networks Protocol Stack Architecture of The NGN

As is shown in figure 2, the access networks protocol stack of the NGN is based on IP Over MPLS Over ATM Over mobile and compatible with IPV6. That is, this access networks protocol stack uses TP (tunnel protocol) or MTP (modified tunnel protocol) to realize cooperative working of multiple access networks. And, it integrates the common heterogeneity networks with different architectures by matching in cross layers and optimizing. So, it sets up the access networks protocol stack of the next NGN with information sharing.

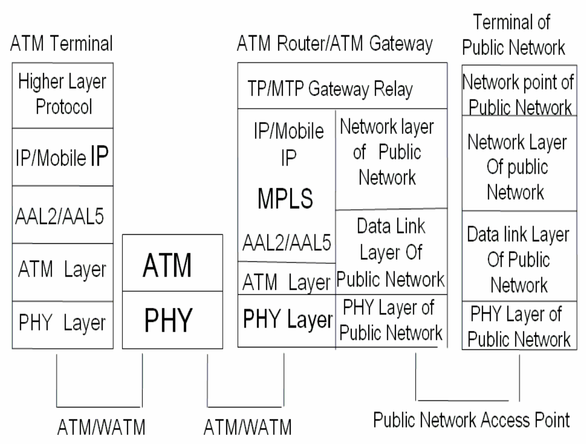

Fig. 2. Access Networks Protocol Stack Architecture Of The NGN

- TP/MTP

Tunneling Protocol (called TP for short) or Modified Tunneling Protocol (called MTP for short) is used at the network interface to realize the remote access to VPN. MTP compresses the information of the packet head and improves the efficiency of the wireless resource.

B. IP QoS Over MPLS Model In Next Generation Network

There are currently two main approaches by the IETF to provide IP QoS in the Internet. These are integrated services (IntServ) and differentiated services (DiffServ). IntServ requires that the router keep the states of every data stream. It uses the resource reservation protocol (RSVP) to reserve the network resource (bandwidth) for every data stream. DiffServ classifies the data stream into several kinds class and only requires the router to keep the state of the every class.

The next generation network is the all-IP mobile network, which merges the wired, and wireless and fixed and mobile network. Although IntServ and DiffServ provide some concepts and frameworks of IP QoS for the NGN, these models cannot be applied because of the characteristics of the NGN. It is difficulty to reserve the network resource for IntServ. RSVP is not suitable for the NGN. RSVP needs the connection setup and release, which will become very frequent. DiffServ need accurate the states of every data stream (bandwidth, delay, packet loss rate etc.) and global topology information, but it is hard to maintain due to the network dynamics (e.g. mobile networks, Ad-hoc) in the NGN environment. Therefore, new IP QoS models are needed for the NGN.

In the ISO/OSI reference model, the different layers behave independently and there is no interaction between them. This layered reference model is designed for wired networks. Different layers need to interact with each other in order to optimize the limited and varying wireless network resource in the NGN. In some sense, whether IntServ or DiffServ is the technology on the third layer and doesn't interact with the low layer technology. However, the network layer can't accurately obtain the network state information and only the switch technology of the link layer can accurately obtain the network state information. In wireless networks, TCP layer needs to know whether a time-out event is resulted from a transmission error or network congestion, in order to avoid starting unnecessary congestion control [9]. In order to provide IP QoS support for the NGN, several protocol layers should cooperate with each other closely and provide the useful information to other layers. By examining the various characteristics of MPLS, it can be seen that MPLS is a very good candidate for providing differentiated servces. The merge of MPLS and DiffServ has many advantages for the next generation network transmission with the support of All-IP QoS. The hybrid model by DffServ over MPLS supports IP QoS by combination the DiffServ model and MPLS technology. DffServ over MPLS inherits that DiffServ can realize All-IP QoS and can provide good scalability for providing QoS.

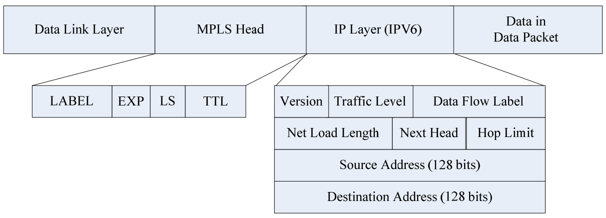

Fig. 3. MPLS and IPV6 Structure Figure with All-IP Network.

A generic mapping from the DiffServ classes to the corresponding layer 2 traffic classes and parameters is need. Furthermore the label switching routers participating in the DffServ over MPLS capable network must be DiffServ compliant. The router needs corresponding improvement in the backbone based on DffServ over MPLS model. The edge router in DffServ over MPLS domain makes dispatch processing such as reforming and discarding for the packet on the basis of the TC field of IPV6. And the processed label is mapped to the EXP field of MPLS label. As is shown in the figure 3.

V. SCALABLE CODING & QOS CONTROL IN THE NGN

Scalable video coding and the quality of serves (QoS) is the next generation networks (NGN) key technique in order to adapt various clients' requirement (e.g. quality, spatial resolution and temporal resolution) and bandwidth variation in heterogeneous network. We propose a reduced dimension scalable video coding using wavelet transformation and QoS control method based on fractal interpolation for the next generation network, and realize different types of bit-stream decoders with different complexity and access bandwidth can coexist.

A. Video Object Scalable Video Object Coding Using Wavelet Transformation

MPEG-4 video coding standard provides object-based functionalities by introducing a concept of video object plane (VOP). With the tracking of video object and allocating different number of bits or different frame rates for different object, the standard can support object-based scalability that is useful in many civil and military applications. Segmenting a video frame into video objects enables the application of different coding strategy and error control according to the importance of video objects. In order to reduce the complexity of segmentation, we propose to reduce the dimension of video, i.e., select D 9/7 wavelets with lifting scheme to transform the video frame to several levels and use the image in low frequency sub-band as its approximation in lower dimension. Then in the transform domain, we segment the lower dimension image into several independent, spatially scalable lower dimension video objects described by wavelet coefficients.

After that, the coefficients are quantified using a uniform scalar quantifier with a dead-zone of twice the step size. The quantify coefficients are encoded by a partial bit-plane embedded entropy coder with context arithmetic coding. Based on different compression rates or different bandwidth of transmission channel in the NGN, the video object sub-band is first ordered from the lowest video object to the highest video object. At the same scale, it will is ordered by LL, LH, HL, and HH. Since there have most of information in the lowest frequency sub-band, a coefficient of the lowest frequency sub-band video object will be coded by DPCM firstly. All coefficients of the high frequency sub-band video object will be code by the 2-D wavelet compression (2-DWT) [10].

B. *QoS Control Using Fractal Interpolation*

The original image is made of several levels wavelet transform using D9/7 wavelet, and obtain every level video objects to segment from the low frequency sub-image and high frequency sub-image of the several level (as is shown figure 4 and figure 5).

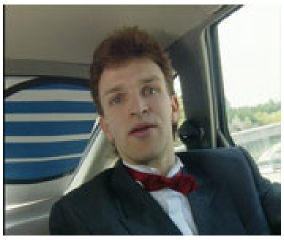

Fig 4. Original image

Fig 5 Image after three levels wavelet transforms caption.

In order to realize QoS control, the low frequency video object, the different scales high frequency video object and background are adopt the different priority cell in DiffServ over MPLS. Because the low frequencies video object contain a majority of the image information to use the most priority cell, and the large scales high frequency video objects are adopt the more priority cell, other small scales high frequency video objects and background are adopt the low priority cell. When the channel is congests or transmission error, the network is the lost low priority cell and transmit high priority cell to realize different error protection.

In order to adapt to various clients' requirement (e.g. quality, spatial resolution and temporal resolution) and bandwidth variation in the NGN, some low scale high frequency components may be dropped according to priority and available transmission bandwidth. According to the similarity of high frequencies in the same orientation at different scales, at the receiver side, we can recover high frequency components at low scales by performing bi-linear interpolation or fractal interpolation on received high frequency component at large scale. To facilitate this adaptive transmission scheme, coding of video frames in wavelet transform domain should be done according to the priority of each component. Thus improve the quality of the reconstructed video to satisfy the different clients' quality requirement in sensor networks.

Bi-linear interpolation is as following:

Set M as original image, N as interpolated image.

$$N(i,j)=\begin{cases} m(\frac{i}{2},\frac{j}{2}) & i,j \text{ are even} \\ \frac{1}{4}[M(i-1,j-1)+M(i-1,j+1)+ \\ M(i+1,j-1)+M(i+1,j+1) & i,j \text{ are odd} \\ \frac{1}{4}[M(i-1,j)+M(i,j-1)+ \\ M(i+1,j)+M(i,j+1) \\ \text{one of } i,j \text{ is odd, the other is even} \end{cases}$$

Fractal interpolation is as following:

Set M as original image, N as interpolated image.

$$N(i,j)=\begin{cases} m(i,j) & \text{i,j are odd} \\ \frac{1}{4}[M(i-1,j-1)+M(i-1,j+1)+ \\ M(i+1,j-1)+M(i+1,j+1)]+ \\ \sqrt{1-2^{2H-2}}\cdot\|\Delta x\|\cdot H\cdot\sigma\cdot G & \text{i,j are even} \\ \frac{1}{4}[M(i-1,j)+M(i,j-1)+M(i+1,j)+ \\ M(i,j+1)]+\sqrt{1-2^{2H-2}}\cdot\|\Delta x\|\cdot H\cdot\sigma\cdot G \\ \text{one of i,j is odd, the other is even} \end{cases}$$

VI. SIMULATION RESULTS AND DISCUSSIONS

The simulation is performed on a Pentium IV Personal computer. We selected the luminance component of the first 300 frames of Boat in coastguard, anchorpersons in News, and Foreman. The size of each individual frame of each sequence is 176×144 pixels.

In the first experiment, we select D9/7 wavelet filter bank to transform the test sequences to two levels. Because the low frequency sub-band contains a majority of the image information, the low frequency is protected and the high frequencies are discarded first in the case of network congestion or transmission error. In order to satisfy the quality requirement of different clients, according to the similarity of high frequencies in the same sub-band at different scale [11], the receiver can use wavelet fractal interpolation or bi-linear interpolation to recover the lost high frequencies, thus improve the reconstructed image quality to satisfy the quality requirements of different clients. We compare our wavelet fractal interpolation algorithm (called WFI for short) with the Bi-linear interpolation (called BLI for short) and no interpolation (called NI for short) [12] in the peak signal-to-noise ratio (PSNR). Table 1 compares the test sequences average performance.

Simulation results in Table I show that WFI is superior to BLI and NI in the performance of PSNR. Comparing with the NI, the PSNR of WFI algorithm increases 4.5 dB for Boat sequences. With compassion to BLI algorithm, the PSNR of WFI algorithm increases 1.5dB.When the channel is congested, the network may drop high frequency sub-band and transmit low frequency sub-band. Then, the receiver can recover the dropped high frequency by WFI or BLI to meet different clients' requirements.

TABEL1 . Comparison of of PSNR FOR THREE ALGORITHMS

Sequence	WFI (dB)	LI (dB)	No interpolation (dB)
Boat in coast	34.64	33.51.	30.41
News	33.43	32.35	28.63
Foreman	32.86	31.40	29.23

The second experiment was conducted to compare the proposed Differentiated Services over MPLS and WFI (DiffServ over MPLS and WFI) with Differentiated Services (DiffServ) and Best-effort. We use 300 frames of anchorpersons in News, Boat in coastguard and Foreman QCIF sequences. Boat has the least motion and foreman has the most motion. New has the median motion between the other two. All the sequences are coded in the manner that the first picture of every 15 picture is coded in INTRA mode with other picture coded in INTER mode. The results are shown in Table 2. The new algorithm (DiffServ over MPLS and WFI) is superior to DiffServ and Best-effort by improving PSNP with 1.45 dB, and 2.5 dB, respectively. The subjective quality of DiffServ over MPLS and WFI surpasses that of other schemes. It is obvious that the DiffServ over MPLS and WFI can get the best image quality among all the schemes.

TABEL2 . Video object coding result USING QoS CONTROL

Sequences	Bit rate (kbps)	DiffServ over MPLS and WFI (dB)	DiffServ (dB)	Best-effort (dB)
Boat in coast	64	34.45	33.02	31.87
Boat in coast	128	35.99	34.69	33.44
News	64	32.83	31.15	30.81
News	128	33.65	32.34	31.78
Foreman	64	31.75	30.59	29.35
Foreman	128	32.72	31.50	30.83

VII. CONCLUSIONS

We have presented architecture of the NGN for information sharing, and set up IP over MPLS protocol stack and DiffServ over MPLS models to realize the cooperation of heterogeneous networks and QoS control. When the channel is congests, the network is the lost high frequency sub-band and transmit low frequency sub-band, and the receiver can recover the lost high frequency by WFI to satisfy different clients' requirements in the NGN

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REFERENCES

[1] N. Niebert et al., "Ambient networks: An Architecture For Communication Networks Beyond 3G," IEEE Wireless Communication, April 2004, pp.14 – 21.

[2] R.Braden, D.clark et al., "Developing A Next Generation Internet Architecture," IEEE Communication, July 2000,pp.1 – 21.

[3] I.Stoica et al., "Internet Indirection Infrastructure," proc. ACM Sigcom 2002,Pittsburgh, PA, Aug. 2002, pp.34 – 39.

[4] D.Clark et al., "Addressing Reality: An Architectural Response to Real Word Demands on the Evolving Internet." Proc. ACM Sigcomm FDNA 2003 Wksp., Karlsruhe, Germany, Aug. 2003.

[5] J.Crowcroft et al., "Plutarch: An Argument For Network Pluralism," Proc. ACM Sigcomm FDNA 2003 Wksp., Karlsruhe, Germany, Aug. 2003.

[6] M.Grittter and D.R.Cheriton, "An Architecture For content Routing Support in the Internet," Proc. 3rd USENIX Symp. Internet Tech. and Sys., Mar. 2001, pp. 37 – 48.

[7] J.D Vriendt et al., Mobile Network Evolution: A Revolution on the Move," IEEE Communication Magazine, April 2002, pp.104 – 111.

[8] A.K.Salkintzis, " Interworking Techniques And Architectures For WLAN / 3G Integration Toward 4G Mobile Data Networks ," EEE Wireless Communication, June 2004, pp.50 – 61.

[9] N.N.kaein, C.B.onnet, "A Gllance At Quality of Service Models in Mobile Ad Hoc Networks, in Proceeding of DNAC 2002,France, Paris, 2002.

[10] Shipeng Li, Weiping Li, " Shape adaptive discrete wavelet transforms for arbitrarily shaped visual object coding", IEEE Trans. On CAS for Video Technology, Vol.10, No.5 pp.243-250, August 2000

[11] Guofang Tu, Can Zhang, "Remote sensing image processing using wavelet fractal interpolation", The third International Conference on Communications, Circuits and Systems 2005 (ICCCAS-O5), Hong Kong, China, 2005

[12] Lei Zhang, and Guofang Tu, "Scalable Reduced Dimension Object Segmentation Based on Wavelet", Proceeding of the SPIE, Visual Communication and Image Processing2003, Lugono, Switzerland, 2003.