ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 7, July 2014

A Survey on Quality of Service Provision in 4G Wireless Networks

Vishalakshi Prabhu H[1], G.S.Nagaraja[2]

Department of Computer Science & Engineering, R.V.College of Engineering, Bangalore, India[1, 2]

Abstract: Worldwide many mobile operators, industry experts, and researchers have diverse visions of potential 4th generation (4G) features and its implementations. 4G networks will be incorporating advanced Internet Protocol version 6 (IPv6) protocol and the signaling will be done through Internet Protocol (IP). There are several key challenges in implementing 4G heterogeneous network. Few of these problems are all IP network, integration across different topologies, security and Quality of Service (QoS). This paper gives a survey and classification of the important QoS approaches proposed for 4G networks. Classification is based on the work done in each protocol layer and Cross Layer Design (CLD) approach. Finally, this paper presents outcomes of survey which includes significant observations, limitations and idea of further research in improving QoS in 4G networks.

Keywords: Quality of Service (QoS), Internet Protocol (IP), heterogeneous network, Cross Layer Design (CLD)

I. INTRODUCTION

The requirement for higher data speed is increasing rapidly, reason being the availability of smart phones, at low cost in the market due to competition and usage of social networking websites. Constant improvement in wireless data rate is already happening. Different network technologies are integrated to provide seamless connectivity and are termed as heterogeneous network.

Long Term Evolution-Advanced (LTE-A) is known as 4G and it is the solution for heterogeneous networks and wireless broadband services. International Mobile Telecommunication-Advanced(IMT-Advanced) represents a family of mobile wireless technologies, known as 4G.

Network evolution is occurring throughout the globe and we are shifting toward an all-IP communications. The core of 4G network is IP and the signaling is done through advanced IPv6 itself. Internet Protocol (IP) describes the format as well as the switching technology of what is popularly called Evolved Packet Core (EPC). Basically IP was termed as a general-purpose data transport protocol in the network layer, but now extended as a carrier for voice and video communications over 4G networks.

Wireless networks in the future will be heterogeneous. Different access networks such as Institute of Electrical and Electronics Engineers (IEEE) 802.15 Wireless Personal Area Network (WPAN), IEEE 802.11 Wireless Local Area Network (WLAN), IEEE 802.16 Wireless Metropolitan Area Network (WMAN), General Packet Radio Service (GPRS), Enhanced Data rate for GSM Evolution (EDGE), Wideband Code Division Multiple Access (WCDMA), Code Division Multiple Access (CDMA2000), satellite network etc are integrated. Selecting the suitable access network to meet the QoS requirements of a specific application has become a significant topic and priority is to maximize the QoS experienced by the user. QoS is the ability of a network to provide premier service to some fraction of total network traffic over specific underlying technologies [1].

QoS metrics are delay, jitter (delay variation), service availability, bandwidth, throughput, packet loss rate. Metrics are used to indicate performance of particular scheme employed.

QoS can be achieved by resource reservation (integratedservices), prioritization (differentiated services). We can apply QoS according to per flow (individual, uni-directional streams) or per aggregate (two or more flows having something in common) basis.

From the QoS point of view, the protocol stack is composed of upper layer protocols (transport and above), on top of IP. Applications can, in this context, be classified according to the data flows they exchange as elastic or real-time. The network layer includes IP traffic control that implements datagram policing and classification, flow shaping, and scheduling. The data link layer may also provide QoS support, by means of transmission priorities or virtual channels. QoS provision in 4G networks is challenging as they support varying bit rates from multiple users and variety of applications, hostile channel characteristics, bandwidth allocation, fault-tolerance levels, and frequent handoff among heterogeneous wireless networks.

QoS support can occur at the network, transport, application, user and switching levels. To meet QoS, we should address the following issues like encryption protocols, security and “trust of information”, different rates, error profiles, latencies, burstiness, dynamic optimization of scarce resources and fast handoff control [2].

Over the past several years there have been a considerable amount of research in the field of quality-of-service support for 4G systems as it’s more challenging than previous generations. Regarding this, some research papers have presented their idea of QoS architectures across all protocol layers.

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

II. LITERATURE SURVEY

QoS solutions proposed for 4G network can be classified based on the layer in which the mechanism works. Although research to provide QoS in 4G network has happened in data-link, physical, transport and application layer, predominant architectures are available in network layer. A different approach is cross layer design for providing QoS in 4G networks where it tries to optimize architecture across adjacent layers. Traditional approach has been to treat the layers as different entities. A higher layer protocol only makes use of services at lower layers and is not concerned about the implementation of service.

TABLE I: LAYER WISE APPROACHES

S.No	Layer	Authors	Approach
1	Application, Transport, Presentation	Perumalraja Rengaraju, Chung-Horng Lung, Anand Srinivasan	QoS-aware security architecture based on Elliptic Curve Diffie Hellman (ECDH)
2	Transport, Network	Pedro Fortuna1 et al	Header compression to save bandwidth
3	Network	Rui et al	End-to-End QoS based on DiffServ
4		V. Marques et al	IP based QoS approach with AAAC
5		Joachim Hillebrand	QoS signaling architecture
6		Koch	Adaptive resource control
7		Martin et al	Smart scheduler in LTE
8		Fumio Ishizaki et al, Mohsin Iftikhar et al	Packet scheduling algorithms
9		Mohsin Iftikhar et al	Translation matrix to maintain QoS
10		P. Rengaraju, Chung-Horng Lung, Srinivasan	XOR network coding for node protection
11		Perumalraja et al	QoE monitoring and E2E Service assurance
12	Data link	D. Wu and R. Negi,	Effective capacity
13	Cross Layer Design(CLD)	Chen at al	Cross layer algorithm and QoS engine
14		F. Ishizaki and G.U. Hwang	An effective bandwidth function (Physical & Data-link layer)
15		J. Tang and X. Zhang	Physical-Data link cross-layer resource allocation scheme

In CLD approach, protocols can be designed by allowing direct communication between entities in nonadjacent layers for resource opimization. CLD in wireless is different mechanism than CLD in wireline.

Layer wise classification and the approaches followed by various researchers is listed in TABLE I.

Marques et al. proposed an IP-Based QoS Architecture which supports multiple access networks and multiple service provider scenarios. It is an integrated management approach to service in the case of heterogeneous network. Mobile network access is based on the association between QoS brokers and Authentication, Authorization, Accounting and Charging systems (AAAC) [3]. QoS signaling architecture which integrates resource management and mobility management is also presented. Architecture is developed with the concept of domain resource manager and capable of supporting various handover types [4]. Few approaches consider core issues in the design of QoS mechanism (e.g. [5]). But they fail to provide a fully integrated QoS approach to IP-based communication for variety of applications and protocols. Usually adaptive applications are disregarded and mobility issues are not taken care.

Rui et al proposes an end-to-end QoS solution for 4G IP-based networks capable of supporting all types of services, from legacy to adaptive multimedia. It also supports user mobility, both intra- and inter-domain across different access technologies [6]. It is a scalable solution, based on DiffServ to provide layered resource control. Resource management is performed on a per-aggregate basis in the core. Several access networks (AN), which are capable of supporting different access technologies, are present in each Administrative Domain (AD). A core subdomain is also present inside each AD to provide interconnection between the access networks through Subdomain Routers (SR). Connection to other administrative domains is provided via Edge Routers (ER). To provide QoS to variety of services, novel functionalities are added to the Access Routers (AR). ARs mark and recognize individual flows. ARs also translate other QoS reservation mechanisms, such as the IntServ [7], Resource Reservation Protocol (RSVP) [8] into Differentiated Service Code Point (DSCP) markings and QoS Broker requests. Collection of all these functions is called Advanced Router Mechanisms (ARM) [9]. In each domain, an Authentication, Authorization, Accounting, Auditing and Charging (A4C) server is available.

Fumio Ishizaki and Gang Uk Hwang proposed an effective bandwidth function with cross layer design concept. It is a useful framework for the analysis of wireless networks. Here Automatic Repeat request (ARQ) and Adaptive Modulation and Coding (AMC) schemes are discussed. They have introduced the effective bandwidth function of the packet service process in order measure the combined effect of the packet transmission error rate at the physical layer and the packet loss probability at the Medium Access Control (MAC) layer. An AMC scheme with N transmission modes is employed by the system. Nakagami-m model is used to model the slowly varying wireless channel. Received Signal-to-Noise Ratio (SNR) per frame is a random variable with Gamma probability density function. Finite State Markov Chain (FSMC) is used to model the wireless channel state. MAC and PHY layers performance is estimated by the packet loss probability and the average Packet Error Rate (PER) respectively. Queuing analysis of the effective bandwidth function satisfies the required packet loss probability by each user and minimizes the average packet transmission error rate [10].

Fumio Ishizaki and Gang Uk Hwang focus on a packet scheduling algorithm by considering multiuser diversity in wireless networks. Throughput of such system is increased by Knopp and Humblet (KH) scheduling but it might result in unfairness between users. Hence most coarse version of KH scheduling, also called CKH scheduling algorithm is used. CKH most coarsely utilizes multiuser diversity. Packet delay performance of individual user and the system throughput under the CKH scheduling is compared with that under Round Robin (RR) scheduling. CKH scheduling always performs better than the RR scheduling for the maximum throughput. For delay performance, CKH performs better than the RR only when the system is in the severe conditions [11].

Martin et al suggest the quality of service in a LTE network with respect to the employed scheduling strategy and the cell-load is investigated. The scheduler needs t be aware of the type of data to be scheduled and the state of

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 7, July 2014

each user. For example, the availability of user-data for transmission or how long a packet belonging to the user has been in the queue already. Classical schedulers are not designed for diverse scenarios. Two new scheduling strategies based on proportional fair scheduling are proposed to overcome this situation. Performance of the classical scheduling strategies is compared to the new approaches in terms of average-delay and throughput by testing them in traffic-situations. Various services are used under different load-situations [12].

Pedro Fortuna1 et al presents a solution for including header compression mechanisms in 4G networks to provide QoS to the real time flows. RObust Header Compression (RoHC) scheme used to compress the headers of IP based protocols such as Real Time Protocol (RTP), User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). RoHC is particularly adequate for wireless links as they are bandwidth constrained and have high bit error rate. The header compression technique is saving resources when packets have a header/payload size ratio is around 1. In the 4th generation of mobile communications (4G), audio and video flows are transported as IP packets and hence need QoS guarantees. RoHC is based on the suppression of header fields because many of the header fields are static in a flow. To build the *context* information, all the header fields have to be sent uncompressed. After the initialization of the *context*, the static and inferable fields are skipped in subsequent RoHC packets. From here on, they carry out only the dynamic fields. More details about RoHC are presented in [13], [14], [15] and [16].

It is useful to judge the user requirements. Tracking the peak times of utilization of services by users can save the bandwidth/cost factors. Aaqif Afzaal Abbasi et al propose this idea. There is a scope to customize the architecture according to the network usage priorities. This will improve a network's QoS performance. This QoS architecture has two main components namely 1).The Services Archives Unit (SAU) and (2).The Cumulative Services Archives Unit (CSAU). The SAU is a server machine with a database of user record and generates log of the services used by customers. Log of services of users can be transmitted to the CSAU to generate a summary of services used in different access networks. This generated summary in graphical form determines the statistics like services used, data rate, bytes consumed, usage time slots of services, breaks and re-logins, network jitter and congestion states. The proposed SAU architecture can flexibility fit in 4G network which is already functional [17].

QoS solutions currently deployed have restricted communication between layers. Application layer entity initiates the transport layer connections (UDP or TCP). It can also set up QoS parameters for established connections separately. The network layer considers QoS requirements to set up IP traffic control. Usually this information is not passed to the data-link layer. Also each link layer has its own QoS characteristics. This creates a fundamental problem in currently deployed QoS subsystems: QoS setup information is not available to some layers in the protocol stack. So they cooperate poorly with the QoS subsystem rather than positively contributing to provide QoS [18].

J. Tang and X. Zhang [19] proposed QoS guarantees over wireless relay networks using Physical-Data link cross-layer resource allocation scheme. The delay information is exchanged in the cross-layer design scheme. Their objective is to maximize the throughput of relay network and minimize the delay QoS constraint. The theory of statistical QoS guarantees **is** combined with the information theoretic results to propose the idea. Their approach revolves around a powerful concept called effective capacity [20]. Original throughput maximization is converted to effective capacity maximization. Delay constraint is characterized by QoS exponent θ. Flat fading channel model is assumed. Effective-capacity-based approach is the efficient CLD strategy as applied to wireless relay networks**.** Problem is deciding what is the optimal relay protocol which is not discussed in this paper. It is to be noted that the performances of different relay protocols differ significantly. If more powerful relay protocols are employed as proposed and studied in [19], we can attain better network performance.

Chen et al proposes cross layer QoS architecture for 4G heterogeneous network services. QoS engine and cross layer algorithms are the main components. QoS engine is composed of QoS daemon, QoS agent and control module. Cross Layer Architecture monitors and adjusts resources periodically. In the absence of CLA, average latency and average packet loss are reduced by 2% and 8.5% respectively. But throughput achieved is slightly lower in CLA than traditional layered approach [21].

Wang, F. Yang, Q. Zhang and Y. Xu [22] proposed an analytical model for multihop IEEE 802.11 networks to calculate how much bandwidth can be utilized along a path without violating the QoS requirements of existing rate-controlled traffic flows. To analyze the path capacity, a notion of "Free channel time" is introduced. It is the time allowed for a wireless link to transmit data. The model characterizes the unsaturated traffic condition to attain goal. The node depicts the interaction between the newly injected traffic and the hidden traffic which would have an effect upon the new traffic.

Based on DiffServ principles for traffic differentiation, Resource Management in DiffServ (RMD) protocol is proposed. It performs an edge-to-edge resource management. RMD is an extension of the DiffServ principles which provides dynamic resource management and admission control. The RMD defines two protocols, Per Domain Reservation (PDR) and Per Hop Reservation (PHR) [23].

Significant research is done by P. Rengaraju, Chung-Horng Lung, and Anand Srinivasan in the field of QoS in 4G. Some of their works are described below.

P.Rengaraju et al have researched on measuring the QoS performance for node protection in 4G wireless networks using network coding. Exclusive OR (XOR) network coding is used to explain the node protection for multihop 4G wireless networks. It is followed by measurement of the QoS performance, such as packet delivery ratio (PDR), latency and jitter, for different scenarios. Failure of a single and two relay node with and without proposed protection scheme is tested along with user's mobility. The simulation results compare the QoS performance with protection against failure of relay nodes to that of no failure scenario. They are almost same. Due to their protection mechanism, network reliability is increased [24].

Worldwide Interoperability for Mobile Access (WiMAX) and LTE are 4G wireless technologies which have better Quality of Service (QoS) and security architectures. Security threats like Denial of Service (DoS), an introduction of malefic node are detected in WiMAX and LTE. So there is a need for strong security mechanisms and strict authentication methods to overcome the existing security threats in 4G multihop wireless networks. But enhancing security should not degrade network QoS. On this line, QoS aware distributed security architecture based on the Elliptic Curve Diffie-Hellman (ECDH) protocol is proposed by P.Rengaraju et al. ECDH is competitor to Rivest Shamir Adleman (RSA) public key algorithm and has very good security. ECDH consumes less power and suitable for 4G wireless networks. Simulation and testbed results for WiMAX networks indicate that the proposed scheme provides strong security and strict authentication for handover users without affecting the QoS performance [25].

To achieve the necessary End-to-End (E2E) QoS in WiMax and LTE networks, authors have considered the existing cross-layer implementations. The Quality of Experience (QoE) is defined by International Telecommunication Union (ITU) as *"overall acceptability of an application or particular service, as perceived subjectively by the end users"*. The QoE is subjective and denotes user's internal state, the characteristics of the designed system, and the environment in which the service can be experienced. QoE can be measured by both subjective and objective metrics [26] Model uses flat IP architecture of WiMAX networks. To provide the WiMAX radio access, Network Access Provider (NAP) maintains the Access Service Network (ASN) [27].

Hussain Mohammed and P.J.Radcliffe propose packet scheduling scheme for 4G wireless to improve QoS in wireless networks. The new packet algorithm modifies IP and radio layers to support Broadband Wireless Access (BWAS) QoS. Concept of fairness is added. Their results provide low handoff packet drop rate, low packet forwarding rate, low packet delay, ensures fairness among the users of different services and generate higher revenue. "Satisfaction Factor" is used to measure the efficiency of various scheduling schemes. A downlink packet scheduler is located at the NodeB's of BWAS. It regulates the distribution of the downlink shared channels to the mobile users by deciding which packet should be transmitted during a given time frame. Major control of the performance attributes of these systems is done by the scheduler. It gives carriers an opportunity to maximize revenue. Algorithm includes a step to eliminate the contention between users whenever they have the same fairness measure value [28].

Jaume Ramis et al discuss_traffic scheduling algorithms for wireless systems. Scheduling algorithms of wireline cannot be applied in wireless due to hostile nature of medium. Scheduling algorithms for wireless can be 1). Centralized or 2). Distributed. Distributed scheduling is mainly applied in adhoc or uplink operation where users contend for channel access. Due to greedy behaviors of nodes, there is no efficiency, fairness and QoS fulfillment that can be done with centralized approach. Paper gives exhaustive survey of centralized wireless scheduling techniques. They are evaluated with relevant performance criteria suitable for next generation networks [29].

Packet scheduling for Voice over IP (VoIP) over LTE-A is presented by Ronnie Mugisha and Neco Ventura. An algorithm which prioritizes delay requirements of the VoIP traffic presents the best overall capacity. Classification of Scheduling Algorithms is discussed and categorized into two types: *QoS differentiated* and *non-QoS differentiated* algorithms. The non-QoS differentiated algorithms are unable to recognize services or the QoS demands of a specific user. Each algorithm has description of the "calculation of a priority function for each specific user." *Non-QoS differentiated* Algorithms are 1) Round Robin Algorithm, 2) Queue Based Max CIR (QBMC) Algorithm 3) The Proportional Fair Algorithm. *QoS differentiated* Algorithms are 1) The Weighted Proportion Fair (WPF), 2) Modified Largest Weighted Delay First, 3) The Exponential Proportional Fair Algorithm [30].

Majority of existing studies on queuing are based on simplistic Poisson model and traditional scheduling algorithms. But research by Mohsin Iftikhar et al presents an analytical performance model for multiple queue systems. Here traffic input is controlled by promising scheduling mechanism. G/M/1 queueing system is used to construct the model as it considers multiple classes of traffic [31].

Idea of translation matrix to maintain QoS for a roaming user is novel and described by Mohsin Iftikhar et al. The parsimonious traffic model is used where only few parameters are used to match measurements. The model is similar to an on/off process. Matrices are maintained by each network to keep track of the traffic behavior of the various traffic classes. As the terminal changes network access, existing flow parameters are compared to possible new reservation classes with the help of matrices. Mechanism to build the matrices and implementation scenario of QoS mapping between two different kinds of access network is explained. Universal Mobile Telecommunication System (UMTS)-to-IP QoS mapping

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 7, July 2014

is performed by a translation function in the Gateway GPRS Serving Node (GGSN) router as suggested by 3rd Generation Partnership Project (3GPP). GGSN router should classify each UMTS packet flow to map it to a suitable IP QoS class [32].

A selection algorithm of 4G network has been proposed to implement user preferences in a better way. Rank based on distance function is computed for various available services/access technologies. Before using the distance function, all the parameter values should be normalized to take on values in the range of zero and one. Values are assigned in such a way that higher the value, better it is for the user. For example a network with billing parameter of 0.8 is more economical than the one having a value of 0.6. *Weighted distance Function is used to implement another* level of customization required in 4G. Users are allowed to give priority to few parameters. For example, users prefer information security during electronic transactions rather than bandwidth or cost [33].

QoE aware vertical handover is proposed by Kandaraj P. et al. One of the Multi-Criteria Decision Making (MCDM) techniques is *Technique of Order Preference by Similarity to Ideal Solution* (TOPSIS). It is deployed by the authors. Too artificial alternatives are hypothesized in this method, namely *ideal alternative* and *negative ideal alternative. Ideal alternative* that has the best level for all attributes considered and *negative ideal alternative h*ave the worst attribute values. Among two alternatives, TOPSIS chooses one that is closest to the ideal solution and farthest from negative ideal alternative [34].

Cooperative architecture is described by Ben-Hamza et al. They consider a hybrid interworking approach composed of overlapping IEEE 802.11 and IEEE 802.16 networks. Four main components of the 802.11 architecture are radio access devices (WiMAX Base station, Wi-Fi Access points), Mobile Nodes (MN) and Hybrid Units (HU). The quality of service of each access technology is taken care by HU entity. The translation and mapping of QoS from Wi-Fi or WiMAX QoS scheme to the proposed service classes and vice-versa is also done by hybrid units. The serving hybrid unit creates the profile of the user during their first admission into the architecture. Since users are mobile, handovers might take place. Cooperative architecture focus mainly on vertical handover with the support of hybrid units. To provide superior QoS, other features are added to each HU [35].

III. OUTCOMES OF SURVEY

1) Majority of the research is in the context of single architectural layers. Work revolves around distributed systems, operating system, transport mechanism, backbone networks or access networks. Progress made in addressing the issue of overall end-to-end support for QoS in 4G wireless networks is not satisfactory.
2) Solutions proposed in [4] assume that the core network is over-provisioned. Hence QoS support is necessary only for the access network. Mobility is not taken care.
3) Even though WiMAX and LTE are fully fledged 4G wireless technologies with superior Quality of Service (QoS) and security mechanisms, some loopholes are identified. Strong cryptographic methods are available but most 4G network terminals are tiny devices. Hence they are memory and power constrained to sustain intense cryptographic computations. Priority to security might in turn degrade QoS experienced by the user.
4) Some QoS schemes very well support specific type of traffic but might perform poorly for different applications. So we need an integrated approach to support multi-user and multiple applications. Also the proposed QoS scheme should be scalable to support ever-growing multimedia traffic generated from social-networking sites.
5) Even though cross layer design approach to meet QoS guarantees exists, it is a violation of the fundamental rule of protocol design. Since protocol layers are allowed to communicate without restrictions to make optimum decisions, complexity of the protocol stack design increases. Any modification to any protocol in the future should pay off.
6) The wired TCP which worked well for decades is aging with the rapid growth of wireless technologies. TCP played dominant role in providing QoS in wired networks. It may be necessary to modify original TCP protocol to fit in 4G networks. TCP should take care of QoS as well as frequent handoffs both horizontal and vertical.
7) Standard solution to overcome the cause of revenue loss has not been discussed in most QoS architectures. So there is scope for enhanced algorithms to support revenue generation depending on premier service demanded by users [28].

IV. CONCLUSION AND FUTURE WORK

There is plenty of related research on providing QoS in 4G networks because cellular networks are shifting from voice centric to flexible data centric networks. This paper provides a review of some of the popular solutions for providing QoS in 4G networks. Although several proposals exist, implementing QoS in real world 4G networks is challenging due to heterogeneity of networks, fast handoff, varying bit rates, propagation conditions and variety of applications. Voice traffic is growing linearly whereas data traffic is growing exponentially. QoS and signaling protocols are able to handle voice over IP in 4G networks. To support big data over 4G networks, IP needs traffic engineering. The QoS plane should receive handover notifications. Proposed architectures would be practical if mobility model and traffic model are taken into consideration. Various QoS mechanisms available for particular applications may be investigated further.

REFERENCES

[1] Ourania Markaki , Dimitris E.Charilas, Dimitris Nikitopoulos, “Enhancing Quality of Experience in next generation networks through network selection mechanisms”, The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Athens, pp.1-5, September 2007

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 7, July 2014

[2] Muhammed Mustaqim, Khalid Khan, Muhammed Usman,"LTE-advanced: Requirements and technical challenges for 4G cellular network", Journal of Emerging Trends in Computing and Information Sciences, vol.3, Issue.5, pp. 665-671, May 2012

[3] V. Marques et al.,"An IP-based QoS architecture for 4G operator Scenarios", IEEE Wireless Communications, Vol.10, Issue.3,pp.54-62, 2003

[4] Joachim Hillebrand, C.Prehofer, R.Bless, M.Zitterbart et al., "Quality-of-Service signaling for next-generation IP-based mobile networks", IEEE Communications, 42(6), 2004, 72-79

[5] Bert F. Koch, "A QoS architecture with adaptive resource control : the AQUILA approach", International workshop- QofIS 2001,Coimbra, Portugal, September 2001

[6] Rui Prior1, Susana Sargento2, Janusz Gozdecki3, Rui Aguiar,"Providing end-to-end QoS in 4G networks", Proceedings of the Third IASTED International Conference on Communications and Computer Networks (CCN'2005), California, USA, 2005

[7] R. Braden, D.Clark, S.Shenker, "Integrated services in the Internet architecture: an overview", IETF RFC 1633, June 1994.

[8] R. Braden (ed.), L. Zhang,S. Berson,S. Herzog S. Jamin," Resource ReSerVation Protocol (RSVP) – version 1 functional specification", IETF RFC 2205, September. 1997.

[9] Diogo Gomes, Pedro Goncalves, Rui L Aguiar,"A transsignaling strategy for QoS support in heterogeneous networks", Proc. ICT' 2004, Fortaleza, Brazil, August 2004.

[10] F. Ishizaki and G.U. Hwang, "Cross-layer design and analysis of wireless networks using the effective bandwidth function," IEEE Transactions on Wireless Communications, Vol.6, No.9, pp.3214-3219, September 2007.

[11] Fumio Ishizaki, Gang Uk Hwang, "Queuing delay analysis for packet schedulers with/without multiuser diversity over a fading channel", IEEE Transactions on Vehicular Technology,Vol.56,Issue.5,pp.3220-3227, September 2007

[12] Martin Klaus Muller, Stefan Schwarz and Markus Rupp, "QoS investigation of proportional fair scheduling in LTE networks", IFIP 2013,Valencia, pp.1-4, Nov 2013

[13] C.Bormann et al, "RObust Header Compression (ROHC): framework and four profiles: RTP, UDP, ESP, and uncompressed", RFC 3095, July 2001

[14] C.Bormann, "Robust Header Compression (ROHC) over PPP", RFC 3241, April 2002

[15] C.Bormann, "Robust Header Compression (ROHC) over 802 networks", Internet Draft, October 2004

[16] K.Svanbro, "Lower layer guidelines for robust RTP/UDP/IP header compression", RFC 3409, December 2002

[17] Aaqif Afzaal Abbasi, Javaid Iqbal, Akhtar Nawaz Malik, "A novel QoS optimization architecture for 4G networks", World Academy of Science, Engineering and Technology,Vol.62, 2010

[18] Gustavcoar Neiro, I Nesc Porto Jose Ruela, Manureicla Ricardo , "Cross-layer design in 4G wireless terminals", IEEE Wireless Communications, Vol.11,Issue.2,pp.7-14, April 2004

[19] J. Tang and X. Zhang, "Cross-layer resource allocation over wireless relay networks for QoS provisioning", IEEE Journal on Selected Areas in Communications, Vol.25, No.4, pp.645-656, May 2007.

[20] D. Wu and R. Negi, "Effective capacity: a wireless link model for support of QoS," IEEE Trans. Wireless Commun., vol. 2, no. 4, pp. 630–643, Jul. 2003.

[21] Jiann-Liang Chen, Ming-Chiao Chen, Shih-Wei Liu, Jyun-Yu Jhuo, "Cross-layer QoS architecture for 4G heterogeneous network services", 11th Int.Conf. Advanced Communication Technology (ICACT 2009),Phoenix Park, pp.73-77,Jan 2009

[22] K. Wang, F. Yang, Q. Zhang and Y. Xu, "Modeling path capacity in multi-hop IEEE 802.11 networks for QoS service," IEEE Transactions on Wireless Communications, Vol.6, No.2, pp.738-749, February 2007.

[23] J.L. Chen, M.C. Chen and Y.R. Chian, "QoS management in heterogeneous home network," Computer Networks, Vol.5I, No.I2, pp.3368-3379, 2007.

[24] Perumalraja Rengaraju, Chung-Horng Lung, Anand Srinivasan, "QoS and protection of relay nodes in 4G wireless networks using network coding", 9th International Conference on Wireless Communications and Mobile Computing (IWCMC), Sardinia ,pp. 282 - 287 ,July 2013

[25] Perumalraja Rengaraju, Chung-Horng Lung, Anand Srinivasan, "QoS-aware distributed security architecture for 4G multihop wireless networks", IEEE Transactions on Vehicular Technology, Vol: PP, Issue: 99 , page 1, November 2013

[26] Fernando Kuipers, Robert Kooij, Danny De Vleeschauwer, and Kjell Brunnstrom, "Techniques for measuring Quality of Experience," Proc. International Conference on Wired/Wireless Internet Communications, Sweden, June 2010.

[27] Perumalraja Rengaraju et al, "On QoE monitoring and E2E service assurance in 4G wireless networks", IEEE Wireless Communications, Vol.19, Issue. (4), pp.89-96 August 2012

[28] Hussain Mohammed and P.J.Radcliffe, "A packet scheduling scheme for 4G wireless access systems aiming to maximize revenue for the telecom carriers", Australasian Telecommunication Networks and Applications Conference (ATNAC-2011), Melbourne, pp.1-6, Nov 2011

[29] Jaume Ramis,Loren Carrasco,Guilem Femenias , Felip Riera Palou, "Scheduling algorithms for 4G wireless networks" ,Personal Wireless Communications, Series: IFIP, Publisher. Springer US, Vol.245, pp 264-276, 2007

[30] Ronnie Mugisha , Neco Ventura ,"Packet scheduling for VOIP over LTE-A", Conference Publications of IEEE AFRICON 2013, Mauritius, Sept. 2013

[31] Mohsin Iftikhar, Nada Al Zaben, Suparerk Manitpomsut, "The most promising scheduling algorithm to provide guaranteed QoS to all types of traffic in multiservice 4G wireless networks", Ninth International Joint Conference on Computer Science and Software Engineering (JCSSE), Bangkok, pp.109-115, May-June 2012

[32] Mohsin Iftikhar, Nada Al Zaben , Suparerk Manitpomsut ,"The implementation of novel idea of translation matrix to maintain QoS for a roaming user between heterogeneous 4G wireless networks", IEEE 37th Conference on Local Computer Networks Workshops (LCN Workshops), Clearwater, FL, pp. 718 - 725 ,October 2012

[33] Amit Sehgal, Rajeev Agrawal, "QoS based network selection scheme for 4G systems", IEEE Transactions on Consumer Electronics, Vol.56, Issue: 2, pp.560 – 565, May 2010

[34] Kandaraj Piamrat, Adlen Ksentini,Cesar Viho, Jean-Marie Bonnin, "QoE-aware vertical handover in wireless heterogeneous networks", 7th International Conference on Wireless Communications and Mobile Computing (IWCMC), Istanbul, pp. 95 - 100 ,July 2011

[35] Nejd Ben Hamza, Slim Rekhis, and Noureddine Boudriga, "Cooperative architecture for QoS management in wireless 4G networks", IEEE Symposium on Computers & Informatics (ISCI), Kuala Lumpur, March 2011

BIOGRAPHIES

Vishalakshi Prabhu has received her B.E and M.Tech degree from Visvesvariah Technological University (VTU), Belgaum, India in the year 2005 and 2009 respectively. She is gold medalist in M.Tech and her specialization is 'Computer Network Engineering'. At present, she is working as Assistant Professor in the department of 'Computer Science & Engineering' in RVCE. She is pursuing her PhD under VTU in 4G networks. Her areas of interest include Wireless Networks, Cryptography, Network Security and Algorithms.

Dr.G.S.Nagaraja is Professor in the the department of 'Computer Science & Engineering' in RVCE. He obtained his PhD from MGR university and his specialization is networking. His areas of interest include multimedia computing, computer organization and operating systems.