An Approach for Bandwidth Reservation in Ad-Hoc Networks Having Infrastructure Support

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Abstract: - In this paper, we propose an efficient Hash Table Node Identification (HTNI) method using which bandwidth for various flows can be reserved in ad-hoc networks having infrastructure support. These networks are often called "hybrid networks". Bandwidth reservation in these networks depends on the type of the traffic and its priorities. We define a bandwidth reservation factor for use in such hybrid network environments. We propose a cross-layer-based architecture for bandwidth reservation to maintain Quality-of-Service (QoS). We use a priority re-allocation method for flows which starve for long time. The proposed method is useful for finding the position of nodes with low communication cost.

Key-Words: - Hash table, hybrid cellular and ad-hoc networks, QoS, bandwidth, priorities.

1 Introduction

In spite of the last several years of research on wireless ad-hoc networks, massive real-life deployments of ad-hoc networks still remain a challenge. Although the freedom of ad-hoc networks from utilizing fixed infrastructure for offering wireless communication services makes them attractive for fast deployment in application domains such as the military and emergency services, they are limited by their ability to efficiently offer global accessibility and web-based services such as file sharing, messenger services and voice-over-IP [38].

Nodes of traditional cellular wireless networks are maintained by a base station manager (BSM) or server for routing. On the other hand, nodes of purely ad-hoc networks behave as routers by relaying messages in order to improve the performance of the network. One of the most important issues in providing ubiquitous communication is mobility management [1], which primarily concern effectively tracking the locations of the nodes. In case of hybrid networks, BSM can be used for effective mobility management, which can be otherwise more challenging in ad-hoc networks, because of their lack in using a dedicated router/server having a network-wide knowledge of the location of the nodes.

Alternative solutions considering integrated ad-hoc and cellular networks (henceforth, simply referred to as "hybrid network", for convenience) have been investigated and are considered to be promising [23],[24],[35],[36],[37],[38],[39],[40]. A hybrid network is formed by integrating traditional wireless networks and ad-hoc networks through existing cellular infrastructures [23],[24]. The introduction of hybrid networks overcomes the limitations of cellular networks while allowing various ad-hoc and other wireless networks to get connected for a service. In such hybrid networks, since users are expected to move around during communication sessions, offering QoS guarantees by assuring minimum bandwidth and priority scheduling is challenging.

In the case of pure cellular wireless networks, the goal of adaptive call admission control is to ensure that there is sufficient bandwidth reservation for handoff, i.e., for transferring an ongoing call in a cell to another. The reserved bandwidth in a target cell is proportional to the traffic intensity in the surrounding cells [3]. In the absence of sufficient bandwidth for handoff, new connections are subject to getting dropped. One common approach used to reduce the connection dropping rate (CDR) is to reserve some bandwidth solely for handoff use [4].

Guaranteeing QoS in networks has been conventionally proposed using two different models – the integrated services (IntServ) model and the differentiated services (DiffServ) model. IntServ uses the per-flow approach to provide guarantees to individual streams, whereas DiffServ provides aggregate assurances for a group of applications. Additionally, a flexible QoS model is proposed in [21] which integrate both the integrated and the differentiated services. But all these approaches fail to solve effective management of bandwidth. In [15], the authors propose having constraints on bandwidth reservation by obtaining neighboring node information, which is critical in reserving bandwidth. We propose the HTNI method, which use hash tables, to obtain neighboring node information with less communication and computation costs. We approach the problem of bandwidth reservation in hybrid networks using the proposed HTNI method.

2 Related Work

Choi and Shin [2] proposed a predictive, adaptive bandwidth reservation scheme for cellular networks. In their work, they aimed to offer QoS guarantees, by trying to control the value of the handoff dropping probability below a certain benchmark. They use the information about the aggregate history of handoffs in each cell to gain an understanding of user mobility, the directions of the mobile terminals and the handoff times. These pieces of information further enable to estimate the amount of bandwidth to be reserved for handoffs. They proposed three types of admission control procedures for accepting various flows, which differ in the number of neighboring base station managers that participate when a new call is evaluated for admission. It should be observed that their approach does not reserve the bandwidth for different type's flows, instead it reserves the bandwidth for handoff nodes. In another work on bandwidth reservation in cellular networks, Misic and Bun [3] proposed a bandwidth reservation scheme for wireless multimedia networks for handoff nodes. In their work, they have proposed a solution for bounding the probability of forced call termination under different changing mobility scenarios and call arrival rates. The forced call terminations can happen because of several reasons, one of which is unsuccessful handoffs because of insufficient residual bandwidth in the target cell. The amount of dropped calls because of unsuccessful handoffs is a measure of the QoS guarantee offered. In yet another work, Lim et al. [4] proposed a Differential Bandwidth Reservation (DBR) scheme for effectively handling call handoffs and admission of new calls in multimedia wireless networks. In their solution approach, the possible path of a mobile terminal that spans over a set of cells is divided into a couple of clusters in the form of sectors. The cells in a sector are further divided into two regions, depending on whether they have an immediate impact on the handoff or not. In the region closer to the handoff initiating cell, there is a check for exclusive bandwidth reservation. If the requested bandwidth is not available, then the possibility of sharing the already reserved bandwidth is examined. In the outer region, where the mobile terminal has a lower probability to move, only bandwidth sharing is used to accommodate more calls. A handoff request is accepted when all the cells of both the regions agree to accept the call. A variation of the DBR algorithm, called User Profile-Based DBR (UPDBR) [4], exploits the moving pattern of a user to make more efficient bandwidth reservation by minimizing the number of participating cells in handoff.

In cellular (single-hop) networks, all stations learn of each other's requirements usually through a control station (i.e. base station). Similarly, the use of a base station simplifies the problem of routing and multicasting in cellular networks. This solution can be extended to ad-hoc networks by creating clusters of nodes in such a way that resource allocation and management functions can be controlled and implemented efficiently. Mobile node clustering [5] and group-based hierarchical structures [6] can be used to effectively support scalable multicasting techniques and mobility management functions in ad-hoc networks.

Let us now review some interesting pieces of bandwidth reservation work that specifically relate to wireless ad-hoc and IEEE 802.11 networks. Li et al. [8] proposed a flow reservation and admission control scheme for IEEE 802.11 wireless LANs using Enhanced Distributed Coordination Function (EDCF) scheduling policies. EDCF concerns offering access to competing channels while supporting QoS. Li et al.'s solution integrates priority reallocation with admission control and thereby improve throughput. In [15], a QoS reservation mechanism for multirate ad-hoc networks (i.e., networks which support multiple link rates) is proposed based on estimating bandwidth constraints. This work has a limitation that it was developed only for static nodes. In the interest of brevity, without elaborating further the other individual pieces of work on QoS guarantees in ad-hoc networks (which is not the focus of this paper), the readers are referred to works reported in [21], [26], [27], [28], [29], [30], [31], [32], [[33] and [34].

In the context of hybrid networks, Luo et al. [23] proposed an architecture, known as a Unified Cellular Ad-Hoc Network (UCAN). This architecture has been evaluated for various routing scenarios and the throughput of the system was improved. In another work, Lao and Cui [24] proposed bandwidth reservation policies for hybrid cellular and ad-hoc networks based on multicast traffic load. Their work was specifically targeted for scenarios when the BSM can select a subset of multicast groups to save bandwidth in ad-hoc networks in cases where the ad-hoc network loses its capability to efficiently accommodate all multicast groups. It should be observed that the main focus of their work was on saving the bandwidth instead of reserving the bandwidth. Other works relating to QoS support (but not specifically relating to bandwidth reservation) for hybrid networks can be found in [35], [36] and [37].

It should be observed that most of the bandwidth reservation schemes were proposed either only for cellular networks, ad-hoc networks, or Wireless Local Area Networks (WLANs). Also, the typical approach used for bandwidth reservation is dependent on the handoff information. Most of the existing works reported in the literature attempt to save the bandwidth of the network by performing effective routing methods. However, our proposed solution aims to reserve bandwidth effectively for hybrid cellular and ad-hoc networks based on a bandwidth constraint termed as, QoS Factor for Reserving Bandwidth (QFRB). The proposed solution handles all types of flows and reserves bandwidth based on priorities. The QFRB is designed such that it utilizes the maximum available bandwidth (MAB). A Connection Admission Control (CAC) mechanism is designed to handle various flows by using hash tables at BSMs which provide information about the mobility of nodes. HTNI is used to create a unique name and address and help in performing key computation for a node in ad-hoc network. We use a cross layer-based QoS model [22] to categorize various flows for service differentiation as well as reservation. To maintain QoS for various flows a priority re-allocation method [8] is used.

3 Proposed Solution Approach

The primary focus of this work is to reserve the bandwidth for real-time and non-real-time (best effort) flows. The proposed system architecture uses Cross Layer Interactions And Service Mapping (CLIASM) [22]. The proposed architecture aims to provide CLIASM [22] to the network layer and to its lower and higher layers. The network layer collects the information from the application layer and forms the ad-hoc network. The ad-hoc network is further classified into hierarchical regions based on mobility, and then these regions are mapped to the BSM of a cellular network. A hash table is created and stored in the BSM as well as in its neighbors. The main operations on the hash table are node entries and node deletions. A node entry takes place when a node enters into a region and a node deletion takes place when a node leaves the current region. The use of hash table is to find the current location of the node of the mobile network. The Ad-Hoc On-Demand Distance Vector (AODV) [RFC 3561] routing protocol is employed to find multiple paths between the source node and the destination node. Then the CAC estimates the available bandwidth and reserves the same for real-time and non-real-time flows. There are two types of admission control procedures used. One is for real-time flows and another one is for non real-time flows. The real-time flows will be treated as high priority flows and Maximum Available Bandwidth (MAB) is reserved for such flows and the remaining bandwidth will be given to non-real-time flows as they are treated as low priority flows. The congestion control mechanism gives feedback about buffer overflow to CAC so that CAC would take decision on admission of flows. A priority-based buffer management scheme is introduced to schedule the packets. The buffer management is done using two buffers, i.e., one is real-time and another one is for non real-time traffic. The real-time flow buffer stores priority information about flow. The priority information is obtained using the Usability Factor (UF). The UF computation for flows is useful if there exists many flows in buffer. The calculation of UF depends on three factors, namely:

(1) QFRB
(2) Length of flow
(3) Actual path required.

Sometimes the low priority non-real-time flows may starve due to MAC 802.11 EDCF scheduling policies. Hence a priority re-assignment scheme is introduced for low priority flows to avoid starvation. Re-assignment of priorities is also performed based on UF computation for low priority flows. A congestion control mechanism is developed to improve the performance. Explicit congestion notification (ECN) [41] is initiated on noticing overflow of buffers. ECN relies on the ability of the network to detect congestion. In contrast to the traditional congestion avoidance methods like packet dropping, ECN-based congestion mechanism is able to react on incipient stages of congestion. ECN is a congestion avoidance scheme that uses marking packets instead of dropping them in the case of incipient congestion. The receivers of marked packets should return the information about marked packets to the senders, and the senders should decrease their transmission rate. To avoid heavy congestion, routers mark packets with probability depending on an average queue length.

4 Performance Evaluation

For estimating the performance of the proposed mechanism, the following metrics were used:

- **Packet Delivery Throughput:** It is defined as the amount of data packets received by the destinations to those sent by the CBR sources.
- **End-to-End Delay of Data Packets:** It is defined as the delay between the time at which the data packet originates at the source and the time it reaches the destination. Data packets that get lost en route are not considered. Delays due to route discovery, queuing and retransmissions are included in the delay metric.

Performance of our approach was evaluated by comparing with the performance of RSVP and EDCF reservation policies. The results are shown in Fig. 1 and Fig. 2. As seen from these figures, the performance of the proposed system is improved when compared with the existing reservation and non reservation policies.

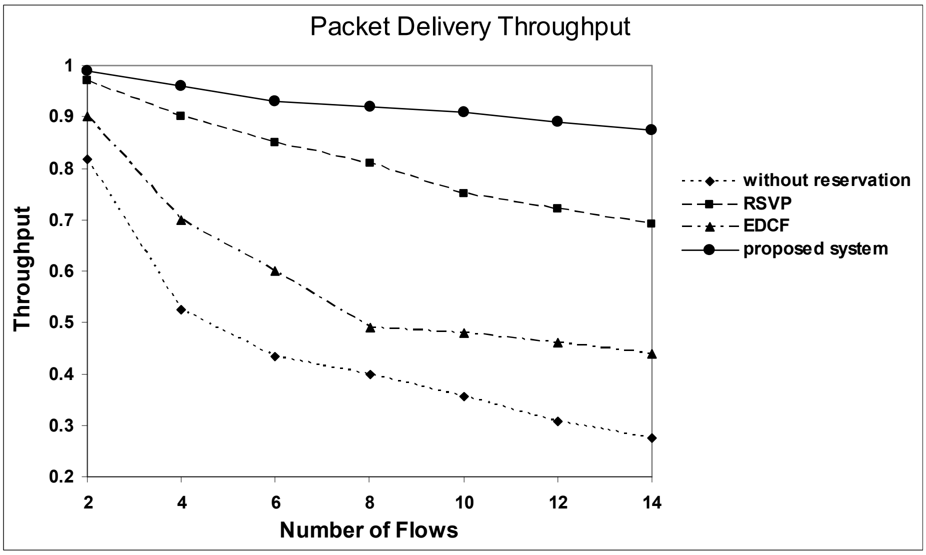

Fig. 1: Comparison of Packet Delivery throughput

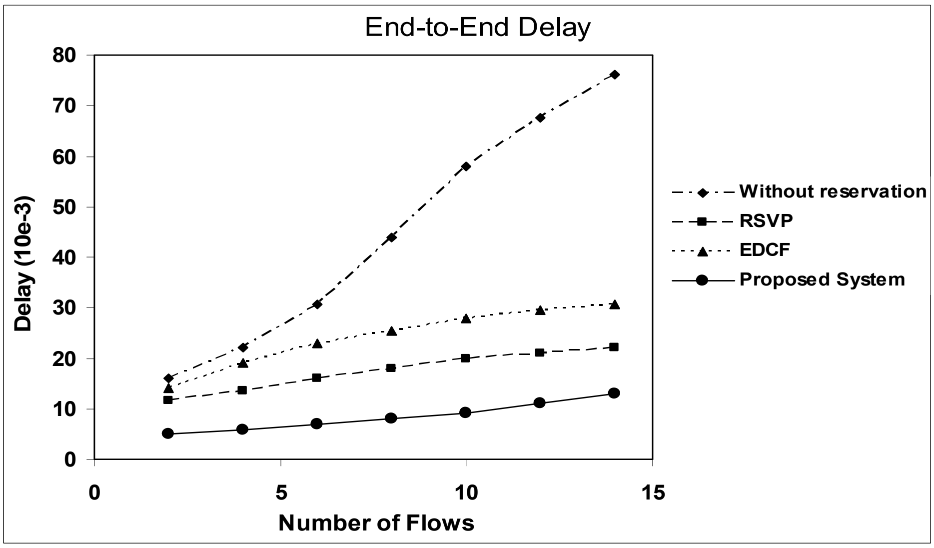

Fig. 2: Comparison of End-to-End Delay

5 Conclusion

In this paper, a bandwidth reservation scheme was presented based on AODV multi-path routing method for hybrid networks. A QoS based bandwidth factor, QFRB, was defined to reserve the bandwidth for such hybrid networks. A new QoS architecture has been developed based on cross-layer concepts. The proposed scheme is effectively analyzed and proved based on the performance metrics like packet throughput and end-to-end packet delay with respect to the flows. It is observed that the introduction of hash tables at base stations makes it easier to trace user mobility.

The performance parameters packet delivery throughput and end-to-end delay are compared for two cases – with reservation and without reservation. It is observed that packet delivery throughput and and-to-end delay are estimated to be good for the proposed system.

References:

[1] K. Y. Eng, M. J. Karol, M. Veeraraghavan, E. Ayanoglu, C. B. Woodworth, P. Pancha and R. A. Valenzuel, "A Wireless Broadband Ad-Hoc ATM Local-Area Network", *IEEE Wireless Networks* , pp-161-174,1995.

[2] S. Choi and K. G. Shin, "Predictive and Adaptive Bandwidth Reservation for Hand-Offs in QoS-Sensitive Cellular Networks", *Proceedings of the ACM SIGCOMM'98*, Vancouver, BC, Canada, pp. 155-156, 1998.

[3] J. Misic and T. Y. Bun, "On Call Level QoS Guarantees Under Heterogeneous User Mobilities in Wireless Multimedia Networks", *Proceedings of the IEEE Global Telecommunications Conference - GLOBECOM'99*, Rio De Janerio, Brazil, pp. 2730-2736, 1999.

[4] S. Lim, G. Cao, and C. R. Das, "A Differential Bandwidth Reservation Policy for Multimedia Wireless Networks",*Proceedings of 2001 International Conference on Parallel Processing Workshops*, Valencia, Spain, pp. 447.2001.

[5] B. An and S. Papavassiliou "A Mobility-Based Clustering Approach to Support Mobility Management and Multicast Routing in Mobile Ad-Hoc Wireless Networks", *International Journal of Network Management*, Vol. 11, No. 6, pp. 387-395, 2001.

[6] W. Kieb, H. Fubler, J. Widmer and M. Mauve, "Hierarchical Location Service for Mobile Ad-Hoc Networks", *ACM SIGMOBILE Mobile Computing and Communications Review,* Vol. 8, No. 4, pp. 47-58, 2003.

[7] P. N. Pathirana, A. V. Savkin and S. Jha, "Mobility Modelling and Trajectory Prediction for Cellular Networks with Mobile Base Stations", *Proceedings of the ACM MobiHoc'03*, Annapolis, Maryland, USA, June 1–3, pp. 213-221, 2003.

[8] M. Li, B. Prabhakaran and S. Sathyamurthy, "On Flow Reservation and Admission Control for Distributed Scheduling Strategies in IEEE 802.11 Wireless LAN", *Proceedings of the 6th ACM International Workshop on Modeling, Analysis, and Simulation of Wireless and Mobile Systems – MSWiM'03*, San Diego, CA, USA, September 19, pp. 108-115, 2003.

[9] A. Futernik, A. M. Haimovich and S. Papavassiliou, "An Analytical Model for Measuring QoS in Ad-Hoc Wireless Networks", *Proceedings of the IEEE Global Telecommunication Conference – GLOBECOM '03,*San Francisco, CA, USA, December 1-5 , pp. 216-220, 2003.

[10] J.-Y. Chang and H.-L. Chen, "Dynamic-Grouping Bandwidth Reservation Scheme for Multimedia Wireless Networks", *IEEE Journal of Selected Areas in Communications,* Vol. 21, No. 10, pp. 1566-1574, December 2003.

[11] W. Liu, X. Chen, Y. Fang and J. M. Shea, "Courtesy Piggybacking: Supporting Differentiated Services in Multihop Mobile Ad Hoc Networks", *IEEE Transactions on Mobile Computing*, Vol. 3, No. 4, pp. 380-393, 2004.

[12] M. C. Domingo and D. Remondo "An Interaction Model between Ad-Hoc Networks and Fixed IP Networks for QoS Support" *Proceedings of the 7th ACM International Symposium on Modeling, Analysis, and Simulation of Wireless and Mobile Systems – MSWIM'04*, Venice, Italy, October 4–6, pp. 188-194, 2004.

[13] Y.-Y. E. Tan, S. McLaughlin and D. I. Laurenson, "Quality-of-Service (QoS) Framework for Multi-rate Wireless Ad-Hoc Network (MWAN) , *Proceedings of the International Workshop on Wireless Ad-Hoc Networks – IWWAN '05*, London, UK, 2005.

[14] H. Hellbrück and S. Fischer, "MINE and MILE: Improving Connectivity in Mobile Ad-Hoc Networks", *ACM SIGMOBILE Mobile Computing and Communications Review*, Vol. 8, No. 4, pp. 19-36, 2005.

[15] L. Cerd, M. Voorhaen, R. Guimar, J.-M. Barcel, J. Garc, J. Morillo and C. Blondia, "A Reservation Scheme Satisfying Bandwidth QoS Constraints for Multirate Ad-Hoc Networks", *Proceedings of the IST Mobile and Wireless Communications Summit,* Dresden, Germany, 2005.

[16] T. Salonidis and L. Tassiulas "Distributed Dynamic Scheduling For End-to-end Rate Guarantees in Wireless Ad Hoc Networks", *Proceedings of the ACM MobiHoc'05*, Urbana Champaign, IL, USA, May 25–27, pp. 145-156, 2005.

[17] A. Capone, J. Elias, F. Martignon and G. Pujolle, "Distributed Dynamic Bandwidth Provisioning in Quality of Service Networks", *Proceedings of the Workshop on QoS and Traffic Control,* Paris, France, December 2005.

[18] Y. Numata and H. Higaki, "Power Controlled Routing in Wireless Multihop Communication for Higher End-to-End Bandwidth", *Proceedings of the*

7th International Conference on Mobile Data Management (MDM'06), Nara, Japan, May 2006.

[19] A. U. H. Sheikh and K. Khan, "Performance of Resource Efficient Routing Protocols for Wireless Ad-Hoc Networks in the Presence of Channel Fading", *Proceedings of the International Conference on Information and Communication Technologies„* Damascus, Syria, pp. 2467-2472, April 2006.

[20] S. Bandyopadhyay, K. Majumder and B. Ghosal", A Circular Layer Location Management Scheme for Mobile Adhoc Networks", *Proceedings of 2006 IFIP International Conference on Wireless and Optical Communications Networks,* Bangalore, India, April 2006.

[21] H. Xiao, W. K. G. Seah, A. Lo and K. C. Chua, "A Flexible Quality of Service Model for Mobile Ad Hoc Networks", *Proceedings of the IEEE Vehicular Technology Conference,* Tokio, Japan, May 2000.

[22] P. Venkata Krishna and N. Ch. S. N Iyengar, "A Cross Layer Based QoS Model for Wireless and Mobile Networks", *Journal of Mobile Communications*, 2007.(in press).

[23] H. Luo, R. Ramjee, P. Sinhaz, L. Li and S. Lu, "UCAN: A Unified Cellular and AdHocNetwork Architecture", *Proceedings of the MobiCom'03,* San Diego, California, USA, pp. 353-367, September 2003.

[24] L. Lao and J.-H. Cui, "Reducing Multicast Traffic Load for Cellular Networks Using *Ad Hoc* Networks" *IEEE Transactions On Vehicular Technology,* Vol. 55, No. 3, pp 822-830, May 2006.

[25] NS-2 simulator: http://www.isi.edu/nsnam/ns/tutorial/ns.html

[26] R. Ramanathan and M. Streenstrup, "Hierarchically-Organized, Multihop Wireless Networks for Quality of Service Support", *ACM Mobile Networks and Applications*, Vol. 3, No. 1, June 1998.

[27] H. Badis and K. A. Agha, "QOLSR, QoS Routing for Ad Hoc Wireless Networks Using OLSR", *European Transactions on Telecommunications*, Vol. 15, No. 4, 2005.

[28] S. B. Lee, G. S. Ahn, X. Zhang and A. T. Campbell, "INSIGNIA: an IP-Based Quality of Service Framework for Mobile Ad Hoc Networks", *Journal of Parallel and Distributed Computing*, Special issue on Wireless and Mobile Computing and Communications, Vol. 60, No. 4, pp. 374-406, April 2000.

[29] C. Zhu and M. S. Corson, "QoS Routing for Mobile Ad-Hoc Networks", *Proceedings of IEEE INFOCOM 2001*, Anchorange, Alaska, USA, 2001.

[30] C. Zhu, "Medium Access Control and Quality-of-Service Routing for Mobile Ad Hoc Networks", Ph.D. Thesis, University of Maryland, College Park, 2001.

[31] P. Mohapatra, L. Jian and G. Chao, "QoS in Mobile Ad Hoc Networks", IEEE Wireless Communications, Vol. 10, No. 3, pp. 44-52, June 2003.

[32] R. Gupta, Z. Jia, T. Tung and J. Walrand, "Interference-aware QoS Routing (IQRouting) for Ad-Hoc Networks", *Proceedings of the IEEE GLOBECOM 2005*, St. Louis, MO, USA, December 2005.

[33] Y. Yang and R. Kravets, "Distributed QoS Guarantees for Realtime Traffic in Ad Hoc Networks", *Proceedings of IEEE SECON 2004*, Santa Clara, CA, USA, pp. 118-127, October 2004.

[34] L. Chen and W. Heinzelman, "QoS-aware routing based on bandwidth estimation for mobile ad hoc networks", *IEEE Journal of Selected Areas in Communications*, Vol. 23, No. 3, pp. 561-572, March 2005.

[35] D. Zhu, M. W. Mutka and Z. Cen, "QoS Aware Wireless Bandwidth Aggregation (QAWBA) by Integrating Cellular and Ad-Hoc Networks", *Proceedings of the First IEEE International Conference on Quality of Service in Heterogeneous Wired/Wireless Networks* (*QShine*), Dallas, TX, USA, Oct. 2004.

[36] E. Yanmaz and O. K. Tonguz, "Dynamic Load Balancing and Sharing Performance of Integrated Wireless Networks," *IEEE Journal of Selected Areas in Communications*, Special issue on Advanced Mobility Management and QoS Protocols for Next Generation Wireless Internet, Vol. 22, No. 5, pp. 862-872, June 2004.

[37] I. Ioannidis, B. Carbunar and C. Nita-Rotaru, "High Throughput Routing in Hybrid Cellular and Ad-Hoc Networks", *Proceedings of the 6th International Symposium on World of Wireless Mobile and Multimedia Networks* (*WoWMoM*), Taormina, Italy, pp. 171-176, June 2005.

[38] Y. J. Song and D. Park, "Infrastructure Support for Ad-Hoc Networks: When and Where", *International Journal of High Performance Computing and Networking*, Vol. 4, Nos. 1/2, pp. 78-84, 2006.

[39] I. Ioannidis and B. Carbunar, "Scalable Routing in Hybrid Cellular and Ad-Hoc Networks", *Proceedings of the 2004 International Conference on Mobile Ad-Hoc and Sensor Systems*, Fort Lauderdale, Florida, pp. 522-524, 2004.

[40] M. Hauge and Ø. Kure, "A Heterogeneous Cellular and Ad Hoc Network Architecture for Multipoint Streaming: A detailed performance analysis", *Proceedings of the Third International Conference on Mobile Computing and Ubiquitous*

Networking (*ICMU 2006*), London, U.K., October 2006.

[41] A. J. Ganesh, Damien Polis, Peter B. Key and R. Srikant, "Congestion Notification and Probing Mechanisms for Endpoint Admission Control", *IEEE/ACM Transactions on Networking*, Vol. 14, No.3, pp. 568-578, June 2006.

[42] S. Kunniyur and R. Srikant, "End-to-End Congestion Control Schemes: Utility Functions, Random Losses and ECN Marks", *IEEE/ACM Transactions on Networking*, Vol. 11, No.5, pp. 689-702, October 2003.