無線メッシュネットワークでのリアルタイム通信のための消費帯域推定によるトラヒック制御方式の提案

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あらまし 柔軟で安価な大規模インターネットアクセスネットワークとして，本グループでは，複数のアクセスポイント（AP）で構成される無線メッシュネットワーク WIMNET の研究を進めている．WIMNET では，ゲートウエイを通じてのインターネットアクセスのために AP 間のマルチホップ通信を行うため，利用可能帯域の低下や遅延増加の問題が発生する．その結果，IP 電話やインターネット会議などのリアルタイム通信は，WIMNET での実現が困難である．本論文では，WIMNET でのリアルタイム通信を実現するために，消費帯域予測による通信トラヒック制御方式を提案する．消費帯域を予測した後，それが WIMNET の利用可能帯域以下となるまで，優先度最小のトラヒックから順に，GW において，その通信を停止する．QualNet シミュレータを用いたシミュレーションにより，提案手法の有効性を検証する．

キーワード 無線メッシュネットワーク，トラヒック制御，通信停止制御，トラフィックシェーピング，消費帯域予測

A Proposal of Traffic Control Method with Bandwidth Usage Estimation for Real-Time Applications in Wireless Mesh Networks

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Abstract As a flexible and cost effective solution for a large-scale Internet access network, we have studied the *Wireless Internet-access Mesh NETwork (WIMNET)* that is composed of multiple access points (APs). WIMNET utilizes multi-hop communications between APs to access to the Internet through a gateway (GW), which becomes increasingly vulnerable to the problems of the available bandwidth degradation and the network latency. As a result, real-time applications such as Voice-over-IP and Video conferences become hard to work in WIMNET. In this paper, we propose a traffic control method with a bandwidth usage estimation to afford real-time applications in WIMNET. After the consumed traffic is estimated, the least priority traffic is repeatedly dropped at GW using the leaky bucket traffic shaping, until it does not exceed the available bandwidth in WIMNET. The effectiveness of our proposal is verified through simulations using the QualNet simulator.

Key words wireless mesh network, traffic control, drop control, leaky bucket traffic shaping, bandwidth usage estimation

1. Introduction

Wireless Internet-access Mesh Network (WIMNET) is a highly promising technology, and it plays an important role in next generation wireless mobile networks. WIMNET have emerged as an important architecture for the future wireless communications. As shown in Fig. 1, WIMNET consists of multiple access points (APs) as mesh routers and mesh clients, and can be independently implemented or integrated with other mobile communication systems such as conventional cellular systems. In WIMNET, at least one AP acts as a gateway (GW) to the Internet. Any host in the field covered by WIMNET can connect to the Internet through GW. WIMNET is dynamically self-organized and self-configured, with nodes in the network automatically establishing and maintaining mesh connectivity among themselves. Besides,

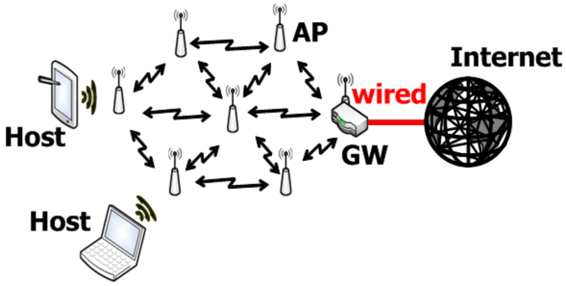


Fig. 1: WIMNET.

WIMNET brings many advantages such as the low up-front cost, the easy network maintenance, the robustness, and the reliable service coverage. In addition to traditional communication services, WIMNET has a potential to deliver real-time services such as the Voice over IP (VoIP), the video telephone and the video meeting. This means that WIMNET can be a competitive alternative to the cellular system.

In WIMNET, all the packets to/from hosts must pass through GWs to access the Internet. If a host is associated with an AP other than GW, the packets must reach GW through multi-hop wireless communications between APs. Since the bandwidth of one link is usually small in wireless networks, the traffic concentration into the limited links around GW increases the communication delay and decreases the performance of WIMNET. Besides, in indoor environments, where WIMNET is mainly deployed, the link quality can easily be degraded by obstacles such as walls, doors, and furniture, which can reduce the transmission speed of the link.

In addition, WIMNET faces the *multi-hop dilemma* [1] that can be defined as problems of the bandwidth degradation, the radio interference, and the network latency caused by multiple traffic "hops". The bandwidth degradation is most severe when the backhaul is shared, as in the single and dual radio approaches. In these cases, each time the aggregated traffic "hops" from an AP to another AP, the throughput is almost cut into half. The radio interference is a serious issue that affects the performance of any wireless network. It can be defined simply as undesired signals that interfere with the normal operation of other radio communication devices. It easily becomes affected by radio interference from neighboring devices that operate in the same band. As a packet traverses the network from a node to another node, the processing delay is naturally introduced. This delay becomes the obstacle for real-time applications in WIMNET.

Several challenges exist for effectively deploying real-time applications over WIMNET. Firstly, in WIMNET, because all the APs share and compete for the spectrum, conflicts can happen among the whole contention domain, which is different from wired networks, cellular networks, and wireless local area networks (WLANs). Under such situations, it is very complicated to compute and manage the bandwidth resources. Secondly, real-time applications such as VoIP usually coexist with best-effort applications such as email, ftp and world-wide web. Real-time applications must compete with other data traffics sharing the transmission media in WIMNET.

To provide very small tolerance for the network latency and jitter, in this paper, we propose a *traffic control method with bandwidth usage estimation* for real-time applications. This method consists of two main modules: 1) the bandwidth usage estimation module using the hop count and traffic bandwidths from clients, and 2) the drop control module using the leaky bucket traffic shaping.

Section 2. describes recent related works. Section 3. presents the design of the traffic control method and modules. Section 4. shows simulation results using Qualnet simulator. Section 5. concludes this paper with future works.

2. Related Works

The issue of providing the QoS guarantee in wireless multihop networks has been widely investigated in the literature, in particular with reference to wireless ad hoc networks. For a survey of QoS approaches for wireless ad hoc networks, readers can be referred to [2]. Given the fully distributed, mobile nature of ad hoc networks, problems of accurately characterizing the bandwidth and delay characteristic of each link is very challenging.

In [3], the authors review the critical aspect that needs to be considered using the IEEE802.16-2004 standard's mesh mode as a case-study. In addition to research challenges, they highlight pitfalls and give pointers to realize QoS in wireless mesh networks. In this paper, we follow their objective to use the efficient and adaptive bandwidth management.

The works more related to ours are given in [4]. The authors have the similar goal to providing the QoS guarantee in terms of the bandwidth and delay constraints to final users. However, this paper is based on 802.11 MAC, and on simplistic interference models based on the notion of the conflict graph. The accuracy of the predicted bandwidth/delay estimation by the proposed framework becomes an issue.

On the other hand, the approach in [5] completely neglects the effect of radio interference, based on TDMA at the MAC later, since it assumes that enough radio resources are available at the backbone nodes so that an arbitrary number of simultaneous transmissions can occur without mutual interference. Unfortunately, this assumption is hardly met in a practical system, where the amount of available radio resources is severely constrained (e.g., only a few orthogonal channels available in 802.11a/b/g).

3. Traffic Control Method with Bandwidth Usage Estimation

3.1 Overview of Traffic Control Method

The goal of the traffic control method is to accept as many real-time flows as much as possible, and to guarantee no impaction of any already accepted real-time flow by additional real-time and/or best effort traffics. Both *IntServ* and *DiffServ* are adopted in the traffic control method to satisfy the bandwidth requirement of real-time applications.

Figure 2 illustrates the flowchart of our traffic control method. This method first classifies the traffics into either real-time applications or best-effort ones. Then, it estimates the *consumed bandwidth* in WIMNET for each real-time flow by multiplying the requested bandwidth ($Bw_{app(i)}$ in the flowchart) with the hop count ($Link_{(i)}$) that indicates the number of links along the path between the host and GW. After that, it calculates the total consumed bandwidth (BWE) by taking the summation among all the real-time flows. If the total consumed bandwidth is larger than the *available bandwidth* in WIMNET, it drops the real-time flow with the largest consumed bandwidth by applying the leaky bucket traffic shaping. This process is repeated until the former one is smaller than the latter one.

Here, we note that through several experiments, we have found that the available bandwidth of a link using IEEE 802.11b protocol for transmitting data is 70% of the designed bandwidth of the link. This means that if each link is assigned 2 Mbps, it actually can send data with 1.4 Mbps.

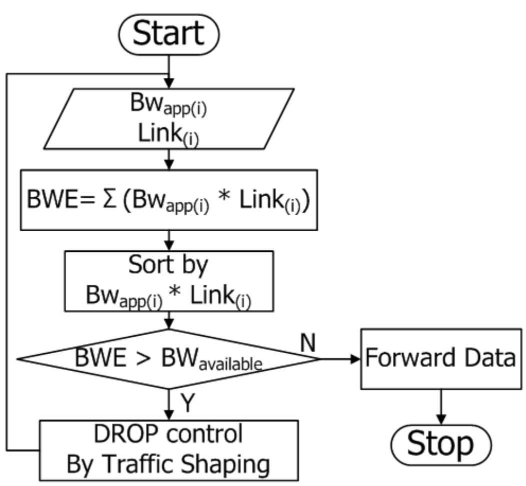


Fig. 2: Flowchart.

3.2 Bandwidth Usage Estimation module

Figure 3 shows an example topology to explain the bandwidth usage estimation. In this example, we assume that

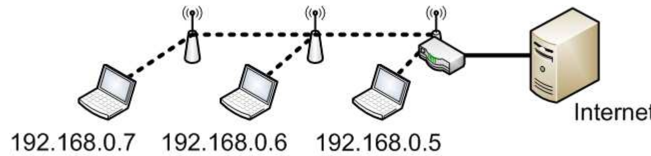


Fig. 3: Example topology.

IEEE 802.11b protocol is adopted with 2 Mbps as the bandwidth of any link, and that any client sends data with 256 Kbps in a real-time application. The client with 192.168.0.5 has one hop count because it is connected directly to GW. The client with 192.168.0.6 has two hop counts, and the client with 192.168.0.7 has three hop counts. Then, the consumed bandwidth can be calculated by:

$$
\begin{aligned}
BWE &= (256 \times 1) + (256 \times 2) + (256 \times 3) \\
&= 1536\text{Kbps}. \qquad (1)
\end{aligned}
$$

3.3 Drop Control Module

When the estimated bandwidth is larger than the available bandwidth, some of the requested flows are dropped. Usually, both of real-time application flows and best-effort flows exist in WIMNET, which may interfere with each other. Thus, our drop control module drops real-time application flows until the estimated bandwidth does not exceed the available bandwidth of the WIMNET while reducing impacts to other flows.

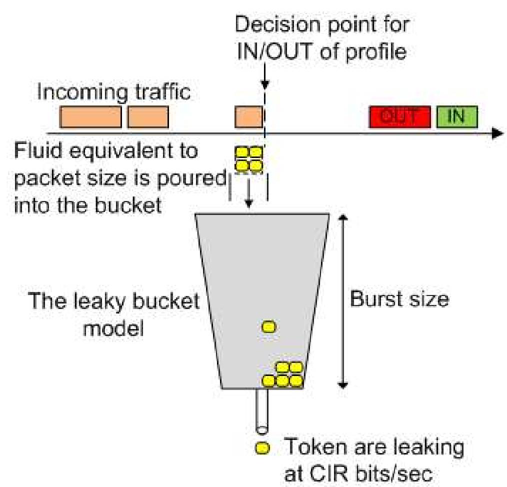


Fig. 4: Leaky bucket operation.

The basic principle of the drop control is to shape the traffic with the drop method in the leaky bucket traffic shaping. The leaky bucket [6] is actually a traffic meter, and is used to measure the amount of information transmitted by a certain data flow. When it is coupled with an algorithmic dropper, it becomes a means of the bandwidth enforcement. The leaky bucket has two parameters: 1) the token rate, 2) the burst tolerance size or bucket size. The toke rate is often called the *Committed Information Rate (CIR)*. Figure 4 shows the operation of the leaky bucket.

For the implementation of the traffic control method in QualNet, we use *TRAFFIC-TRACE* that has been implemented there. In *TRAFFIC-TRACE*, we give a large value to the *Bucket Size* parameter for the traffic accepted by our method. To drop the traffic rejected by our method, we give a small value to the *Bucket Size* parameter, and set *DROP* rather than *DELAY* to the *Action* parameter. To make the constant rate, we give the transmission rate to the *Token Rate* parameter.

4. Simulation Results

4. 1 Simulation Environment

We implement the proposed traffic control method in the Qualnet simulator [7] for evaluation. Here, we prepare two simulation scenarios, namely, 1) the single client for bandwidth threshold measurement, and 2) the traffic control method analysis. The first scenario is aimed to measure the available bandwidth of a wireless link at IEEE 802.11b protocol for the designed bandwidth, and to evaluate the effect of the hop count between a host and GW. The second scenario is aimed to verify the effectiveness of the traffic control method.

In both scenarios, we use two network topologies for the WIMNET backbone, namely, the tree topology in Fig. 5a and the line topology Fig. 5b. The distance between neighboring APs is set 250 m, and the transmission rate of any link between APs is 2 Mbps using IEEE 802.11b protocol. The number of clients is changed from one to three, and the transmission range of any wireless device is fixed to 300 m.

VoIP [8] is adopted as a representative real-time application, so that two programs of *TRAFFIC-TRACE* and *CBR* are used as traffics in Qualnet to simulate VoIP with the leaky-bucket traffic shaping. The six different packet sizes are using including 64 kbps, 128 kbps, 256 kbps, 512 kbps, 1024 kbps and 2048 kbps. Here, we note that we modify source codes in Qualnet to report the bandwidth usage.

4. 2 Single Client for Bandwidth Threshold Measurement

In the first scenario, only one client host is connected to an AP in the line topology, transmitting 2048 Kbps real-time application data. The associated AP of the client is changed among AP1, AP2 and AP3. Figure 6 shows the throughput results. Here, we can see that the throughput for AP1 is about 1.4 Mbps. This means that one hop count gives only around 70% of the designed bandwidth as the available bandwidth for data transmissions. Then, the throughput for AP2 is about 0.75 Mbps, which means that two hop counts give only 35-37% of the designed bandwidth, or the *half* of the available bandwidth for the one hop case. The throughput for AP3 is about 0.45 Mbps, which means that three hop counts give only 22-25% of the designed bandwidth, or the *one-third* of the available bandwidth for the one hop case. We use these results to give the available bandwidth in the traffic control method.

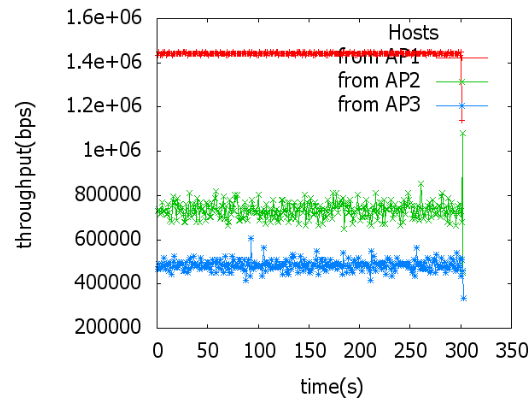


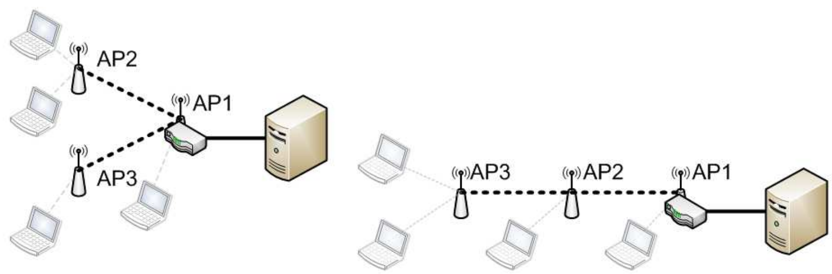
Fig. 6: Throughputs for real-time applications for single client.

4. 3 Traffic Control Method Analysis

In the second scenario, both the tree and line topologies are adopted. The number of client hosts transmitting real-time application data is increased from one to three. The associated AP to each client is also changed from AP1 to AP3, where the number of client hosts increases one by one. Client locations are generated randomly within the circle of the 50 m radius from each AP. *TRAFFIC-TRACE* and *CBR* applications are used as real-time applications and FTP/GENERIC is used as the TCP application. For each topology, both the case with the traffic control and the case without the traffic control are simulated to compare their results. All the clients transmit 256 Kbps data for real-time applications at the same time.

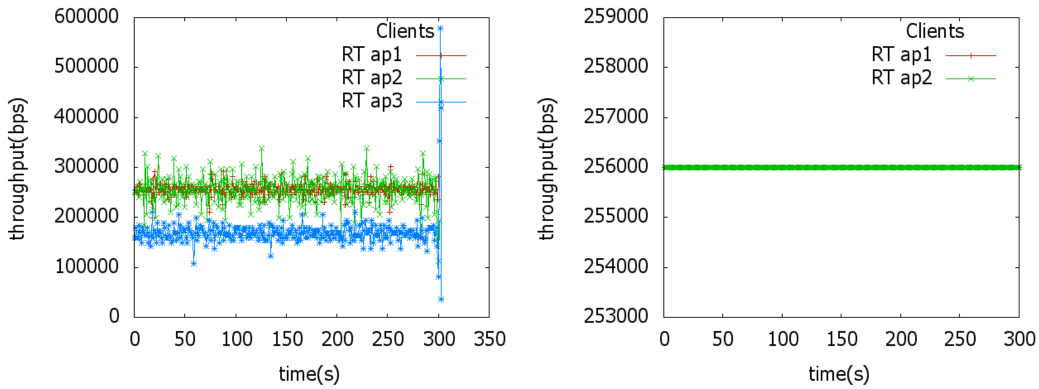
When one client is associated with each AP and all of the three clients are sending data at the same time, our traffic control method drops the traffic from the third client associated with AP3, because the estimated total consumed bandwidth is larger than the available bandwidth and the third client is consuming the largest bandwidth among three clients.

Figures 7a and 8a show that throughputs (transmitted consumed bandwidths) are fluctuated when the traffic control is not adopted. This fluctuation means that the jitter happens in data transmissions. Besides, the third client associated with AP3 cannot achieve the requested throughput where only about 170 Kbps can be sent in Line topology and fluctuated in Tree topology. These results introduce the bad



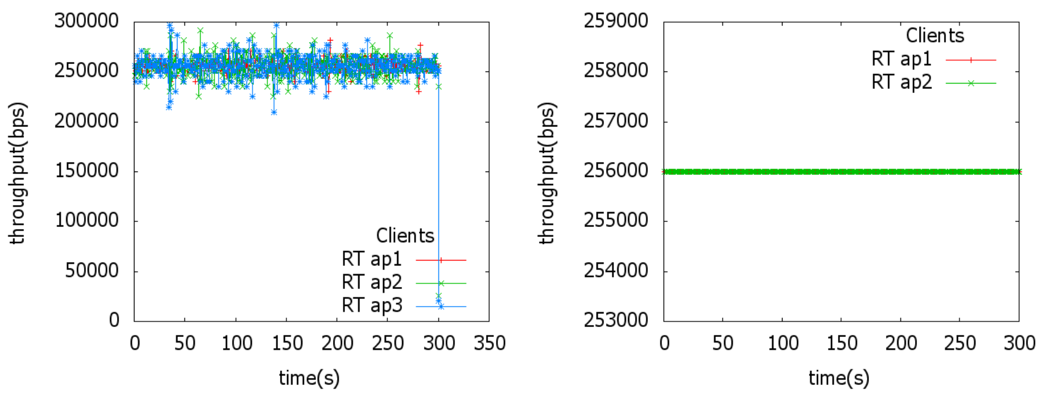
(a) Tree (b) Line

Fig. 5: Topology.



(a) Without traffic control method (b) With traffic control method

Fig. 7: Throughput for real-time application in line topology.



(a) Without traffic control method (b) With traffic control method

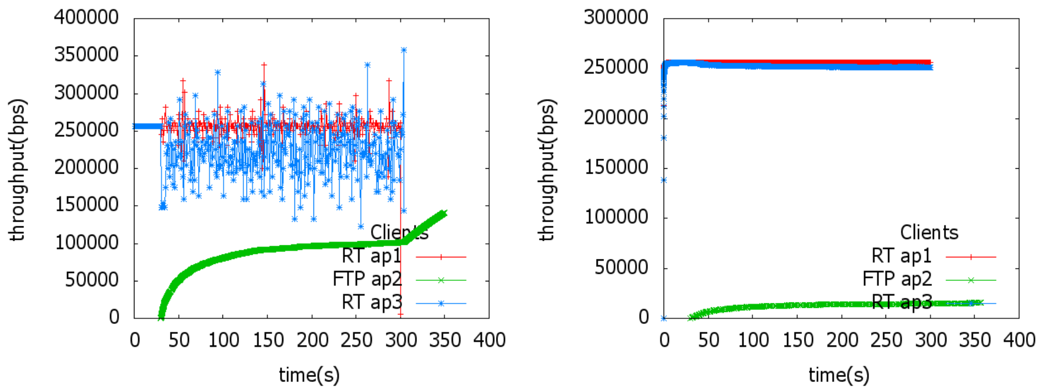
Fig. 8: Throughput for real-time application in tree topology.

quality for real-time applications.

On the other hand, Figs. 7b and Fig. 8b show that the throughput of each client is not fluctuated and are constant at 256 Kbps by dropping the traffic from the third client. This means that the clients can satisfy the real-time applications in good conditions, although the third client needs to give up the real-time application.

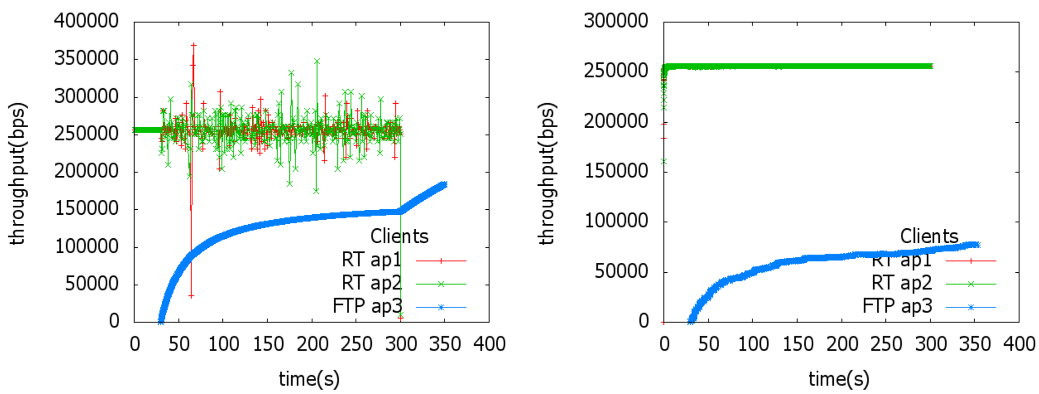
Then, in order to observe the effectiveness of our method in more practical situations where both best-effort applications and real-time applications coexist, the data of one client is changed for a TCP application. As before, both the case with the traffic control and the case without the traffic control are simulated to compare their results. All the clients except for the client requesting a TCP application transmit 256 Kbps data for real-time applications at the same time. Here, we adopt FTP as a TCP application.

Figures 9a and 10a show that without the traffic control, throughputs for the real-time applications are far more fluctuated because of the TCP application. Here, the TCP application consumes the large bandwidth. On the other hand,



(a) Without traffic control method (b) With traffic control method

Fig. 9: Throughput for real-time and best-effort applications in line topology.



(a) Without traffic control method (b) With traffic control method

Fig. 10: Throughput for real-time and best-effort applications in tree topology.

Figs. 9b and 10b show that the throughput of any real-time application becomes constant at 254 Kbps, because the rate of the TCP application is restricted by the traffic control method.

5. Conclusion

In this paper, we proposed a traffic control method for real-time applications in the wireless Internet-access mesh network (WIMNET), and evaluated the effectiveness through simulations using the Qualnet simulator. The traffic control method consists of the bandwidth usage estimation module and the drop control module using the leaky bucket traffic shaping. In future studies, we will improve the accuracy of the bandwidth usage estimation and extend the drop control module by combining the link sharing algorithm. We will also implement the traffic control method using COTS (Commercial Off-The-Shelf) to realize a practical WIMNET system.

Acknowledgments

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文　献

[1] Strix System, "Solving the wireless mesh multi-hop dilemma", White Paper, 2005.

[2] T. B. Reddy, I. Karthigeyan, B. Manoj, and C. S. R. Murthy, "Quality of service provisioning in ad hoc wireless networks: a survey of issues and solutions." Available Online: http://www.sciencedirect.com, April 2004.

[3] P. S. Mogre, M. Hollick, and R. Steinmetz, "QoS in wireless mesh networks: challenges, pitfalls, and roadmap to its realization", 17th Int. Work. Network and Operating Sys. Support. Digital Audio & Video, June 2007.

[4] Y. Wei, R. Maosheng, T. Zhao, L. Xiaoming, "A bandwidth management scheme support for real-time applications in wireless mesh networks", Proc. ACM SAC, pp.2063-2068, 2008.

[5] X. Chu, "Provisioning of parameterized quality of service in 802.11e based wireless mesh networks", Mobile Networks and Applications, vol. 13, pp. 6-18, April 2008.

[6] Leaky Bucket - QoS Guide, `http://qos-guide.com/html/leaky_bucket.html`.

[7] Scalable Networks Technologies, `http://www.scalable-networks.com`.

[8] ITU-T Recommendation G.729A, "Coding of speech at 8kbit/s using conjugate-structure algebraic-code-exited-Linear-prediction (SC-ACELP)", March 1996.