Antcor Polling Optimizer Overview

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1 INTRODUCTION

The nature of current and emerging broadband applications introduces strict requirements for wireless carriers and service providers. The underlying network that is needed in order to support such applications should not only provide adequate bandwidth for data connections but also precise Quality of Service provisioning for real-time multimedia streams.

Many wireless service providers are currently basing their networks on the widely used 802.11 protocol ([1], commonly referred to as ‘WiFi’). Even though 802.11 technology is mature and cheap, it has significant limitations that render it insufficient for supporting modern broadband applications in outdoor deployments. Since the protocol was specifically designed for indoor local area networks, it has major drawbacks when applied outdoors. Moreover, due to the lack of Quality of Service support at the MAC layer, it’s usability is limited to plain Best Effort data transmission.

The limitations of 802.11 technology have been resolved by the more recent IEEE 802.16 family of protocols ([2], commonly referred to as ‘WiMAX’). This protocol stack was designed from the ground up to support outdoor deployments and is based on a highly sophisticated Quality of Service architecture. However the technology is very expensive compared to 802.11 and not widely adopted yet.

Antcor POLLing Optimizer is a proprietary technology that combines the cost-effectiveness and maturity of 802.11 hardware with the benefits of an 802.16-like sophisticated MAC protocol. APOLLO engine achieves an ultimate combination of high network throughput and guaranteed Quality of Service, bringing a new revolutionary era for wireless outdoor broadband deployments.

1.1 802.11 Limitations

The main reason traditional WiFi radios are inappropriate for extended outdoor use is the carrier sense nature of the medium access protocol. In outdoor point to multipoint (PtMP) WiFi networks, every node needs to perform carrier sensing on the medium and transmit whenever a particular frequency is clear. However, in a deployment characterized by long distance links and eventually noise a node may fail to detect activity on the medium and start transmitting concurrently with others, causing packet collisions. This results in increased percentage of packet loss and an overall performance degradation. The problem is intensified by the use of directional antennas which results in the well known “hidden node” issue ([3]). Since it’s difficult for a node to sense activity outside the range of the antenna, the number of collisions increases dramatically to an extent that a station might not be able to successfully transmit more than a few packets. This leads to an overall unfairness and further degradation of network utilization. The RTS/CTS mechanism partially solves but does not completely eliminate the “hidden node” problem and introduces further throughput overkill due to the exchange of additional control frames.

The contention based nature of medium access in traditional WiFi systems is also the main reason for the complete lack of Quality of Service provisioning. Since a node might contend for the medium for an indefinite amount of time, the MAC protocol can not guarantee on time delivery for delay critical data and high throughput for bulk transfers. 802.11e extensions ([4]) were introduced to offer a priority based QoS mechanism, assigning shorter deferral times to higher priority traffic queues. However, 802.11e is also based on probabilistic medium access which results in an inherent inability to provide fair throughput distribution ([5]) and strict QoS guarantees. In conclusion, real Quality of Service can not be achieved with the traditional WiFi products, especially for high load and demanding environments.

Besides the contention based access mechanism (Distributed Coordination Function - DCF), the 802.11 standard also specifies a centralized one, the Point Coordination Function (PCF). In PCF, a central coordinating node polls other stations and allows them contention-free access to the channel. PCF does not suffer from hidden node problems and is more suitable for outdoor environments. However, it is an optional feature of the protocol that is not supported in most commercial products.

2 APOLLO OVERVIEW

APOLLO engine overcomes the limitations of traditional WiFi systems, by adopting a polling scheme that completely eliminates contention. A “Master device” (Base Station - BS), allocates the medium to registered “Slave devices” (Subscriber Stations - SS), by granting their bandwidth requests. The BS coordinates the transmission/reception times of subscriber stations using a sophisticated scheduling scheme. Since an SS is not authorized to access the medium without a grant from the BS, the allocation of resources is deterministic and completely controlled by the BS scheduler.

APOLLO is based on a connection oriented 802.16-like architecture (Figure 1), suitable for providing QoS for Best Effort (BE) and Real Time (RT) traffic. The Scheduler engine is responsible for the optimal and fair allocation of uplink/downlink resources according to the specific requirements of each traffic class. The goal is to maintain high throughput for Best Effort connections while satisfying the delay/jitter constraints for Real Time traffic.

APOLLO protocol stack is implemented as a kernel module that is located above the wireless driver module and right below upper networking layers provided by modern Operating Systems (i.e. IPv4, Bridging) as illustrated in Figure 2. The legacy 802.11 wireless stack is stripped down to the minimum basic transmission/reception functionality (802.11 frame encapsulation/decapsulation, DMA operations and Interrupt handling) that is necessary in order to support the polling scheme. Moreover, two significant features of 802.11 protocol are disabled. The first one is the medium access back-off (CSMA) which is disabled because APOLLO does not rely on any form of contention, and the second one is the 802.11 Acknowledgment mechanism (stop and wait) which is replaced by a custom ARQ (Automatic Repeat reQuest) protocol.

3 APOLLO TECHNOLOGY ASSETS

APOLLO architecture offers an enhanced feature set that addresses the needs and requirements of modern wireless service providers.

3.1 Efficient Bulk-ACK Mechanism

Outdoor wireless deployments are characterized by high speed links of increased distance. The use of per-frame acknowledgment algorithms (such as the one used in IEEE 802.11) is not suitable for these environments since their efficiency is inversely proportional to the bandwidth-propagation delay product ([6]).

APOLLO handles loss detection and retransmissions in a much more efficient way by utilizing a selective repeat Automatic Repeat Request (ARQ) mechanism. Instead of transmitting an acknowledgment for each frame, APOLLO uses Bulk-Acknowledgments that correspond to burst of packets. The Bulk-Ack contains the information that is necessary in order to detect which frames of the burst were lost. Upon reception of this special acknowledgment a node selectively retransmits the lost frames. This technique is more suitable for outdoor

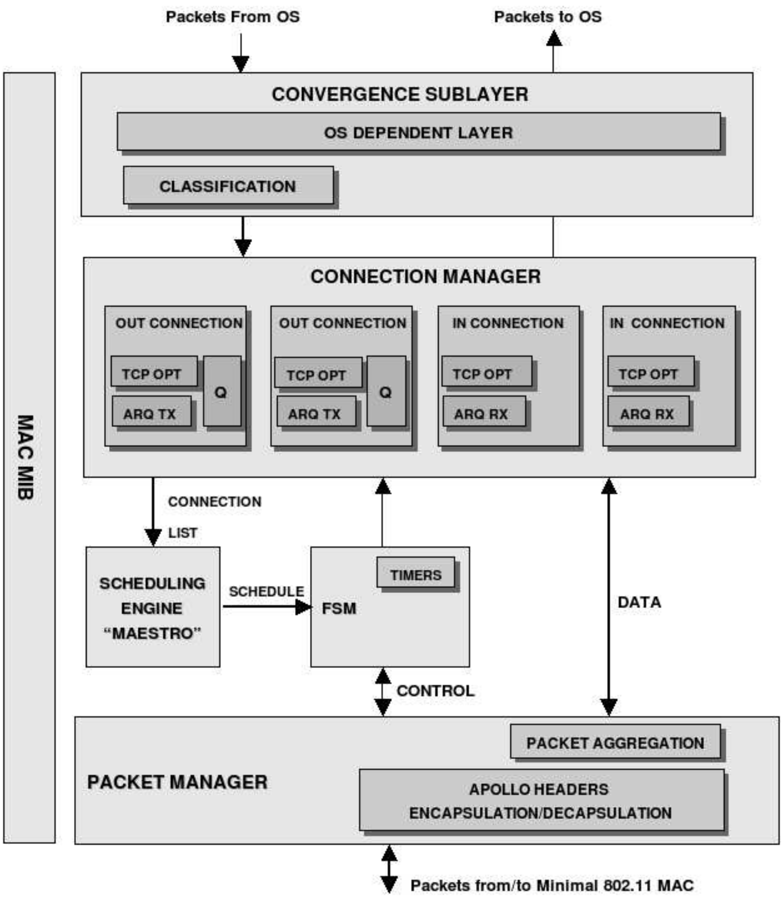

Fig. 1. APOLLO Block Diagram.

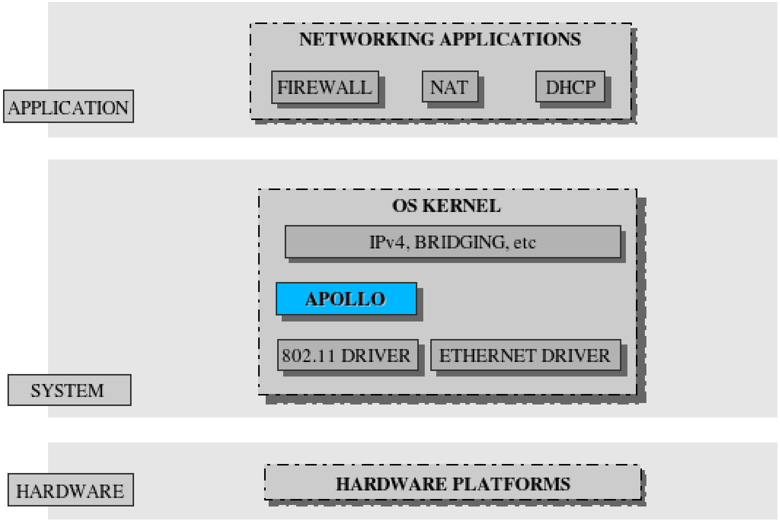

Fig. 2. APOLLO Integration Position.

environments since it minimizes the periods of inactivity between successive transmissions. In this way, a sender can rapidly transmit a burst of packets rather than wait for an Ack after each packet.

3.2 Improved TCP Throughput

Another revolutionary asset of APOLLO is a TCP traffic manipulation module labeled as the TCP Optimizer (TCPOpt). This module performs optimization based on crosslayer interactions between the transport and medium access layers. The TCP Optimizing scheme can increase throughput of the wireless polling network up to 15%. This performance gain can be viewed either as increased Best Effort TCP throughput, or enhanced capacity for Real Time flows. For a double-play WISP deployment, the latter can be translated as the ability to support more concurrent VoIP calls.

TCP Acknowledgment transportation over the wireless link is handled by a custom reliable protocol between APOLLO endpoints. According to this protocol TCP Acks entering the APOLLO network are prioritized and aggregated in a sophisticated way into a single frame. The receiver of the aggregated frame can regenerate and forward the TCP Acks using locally stored information about active TCP connections. This procedure is transparent to the transport layer, i.e. it does not affect end-to-end TCP connections.

TCP and overall performance upswing comes as a result of two major factors.

1) The elimination of small TCP Acknowledgement packets results in significant bandwidth saving on the wireless link.
2) Since aggregated acknowledgments are prioritized, the regenerated TCP Acks are always delivered on-time avoiding unnecessary TCP segment retransmissions that cause throughput degradation.

3.3 Enhanced Network Capacity through Packet Aggregation

Packet aggregation is a technique that leads to higher link utilization and significant reduction of the overall system load (since less frames need to be processed per time unit). It is extremely beneficial for multimedia traffic that is characterized by transactions of small packets at high data rates ([7], [8], [9]). APOLLO integrates an advanced Packet Aggregation mechanism that enhances the capacity of the polling network in terms of active multimedia sessions (i.e. VoIP calls).

3.4 Admission Control

The overall QoS architecture is supplemented with efficient admission control procedures that manage to avoid over subscription problems in a proactive manner: The system prohibits a possible quality degradation for guaranteed services by not admitting additional flows that might cause over subscription.

3.5 Advanced Quality Of Service Scheme (Maestro)

The most important asset of APOLLO engine is the scheduling module, with the codename ‘Maestro’. Maestro implements a sophisticated algorithm that forms the base of APOLLO’s advanced QoS architecture. It is a service aware, flow-oriented scheme ready to be applied to demanding installations to offer guaranteed Quality of Service.

Being an adaptive and self-reconfigurable system, Maestro evaluates the past and present status of the network and performs the necessary actions in order to optimally allocate the network resources with respect to the desired QoS parameters. This dynamic nature provides stability and decent performance of the network over time.

As opposed to priority-based QoS schemes, APOLLO scheduler better enforces SLAs (service level agreements) based on advanced QoS parameters such as minimum reserved, average and peak rates, delay and jitter. This scheme offers potential Service Providers the opportunity to apply custom traffic differentiation and QoS constraints according to their specific needs.

3.6 Hardware and Platform Independent

APOLLO technology is based on off-the-shelf WiFi components and thus eliminates the need for radio modifications or custom hardware. The migration path for converting an existing WiFi-based deployment to APOLLO is extremely fast and cost effective since there is no no need for additional hardware/equipment.

Moreover, since APOLLO was designed as an architecture-independent module, it offers increased flexibility on target architecture selection. Vendors may select from a variety of supported platforms or choose porting to a new one that fits their specific needs and budget. Additionally the modular nature of the implementation allows rapid customizations for specific requirements and feature requests.

4 APOLLO EVALUATION REFERENCE

APOLLO performance has been evaluated through an extensive lab experimentation procedure. Several test scenarios were examined and the overall system's performance has been quantified in terms of metrics such as throughput, fairness, delay and conformance to QoS constraints. The benchmark results indicate how APOLLO competes against the traditional 802.11 MAC and another commercial Polling solution (referred to as Poll from now on). The following section presents a brief overview of some of the most important benchmark results.

4.1 Test Scenarios and Benchmarks

According to Figures 3 and 4, both Polling solutions outperform the traditional 802.11 MAC in terms of UDP/TCP throughput. Performance gains in the range of 5 - 10% stem from the increased overall efficiency (data packets divided by the sum of data plus protocol packets) of the Polling Protocol. Additional performance boost can be achieved by enabling the TCP Optimization Module.

The Scheduling/QoS Architecture performance was evaluated by running several scenarios with a combination of Best Effort and Real Time traffic. The results indicate that APOLLO can maximize Best Effort throughput while maintaining the Real Time delay below the desired target that is set by the administrator.

Figure 5 shows the system's behavior with variable load on the Best Effort flows and fixed rate for Real Time traffic. APOLLO can satisfy the Real Time delay constraint by adjusting the admitted amount of Best Effort traffic. For this specific scenario (30% RT Flow, configured with a desired delay of 60ms) the system could handle up to 40% Best Effort traffic yielding a total throughput of 70% of the nominal Physical Rate. The scheduler does not accept Best Effort traffic above 40%, in order to avoid violating the delay constraint for Real Time flows.

APOLLO regulates Best Effort traffic according to the desired delay for Real Time traffic and the offered Real Time flow. Figure 6 shows the systems behavior when RT flow ranges from 10% to 70% of the nominal physical rate and TCP traffic is transmitted on the BE connections. The scheduler maintains high TCP throughput when Real Time traffic is low. TCP is regulated appropriately when Real Time traffic is increased, in order to avoid QoS violations. The system achieves a total throughput of about 70% on all tests while keeping the RT delay below the desired delay limit (60ms).

Figures 7 and 8 illustrate the delay-throughput trade-off of the system: Relaxed delay constraints yield higher Best Effort throughput. On the other hand, Real Time delay can be minimized at the cost of a slight decrease in BE throughput. The system's operating point can be fine-tuned by the administrator according to deployment requirements. It should be noted that the mean delay of RT traffic is always much below the delay constraint, since APOLLO considers it as an upper bound for worst case RT delay.

One of the most important benefits of APOLLO is increased fairness, both in terms of Uplink/Downlink and Inter-SS throughput distribution. Fairness metrics were extracted for all benchmarks that were performed and the systems fairness was in the range of 80%-100% under all tests (with 100% being the ideal equal throughput distribution on a uniform test). Figure 9 illustrates the throughput distribution under Best Effort saturation. The superior fairness of the polling algorithms stems from the deterministic medium allocation algorithm. The probabilistic nature of medium access in 802.11 MAC seriously impacts fairness even on a perfect deployment without hidden node problems.

APOLLO has also been benchmarked on a 2-play (VoIP + Data) WISP scenario. Figures 10 and 11, show the performance of the system, for variable number of G.711 full duplex calls without Voice Activity Detection (VAD). Worst case Real Time delay was set at 60ms and physical data rate at 36 Mbps. The system can handle up to 90 concurrent (full-duplex, no VAD) calls without violating the delay constraint. VoIP performance metrics indicate that voice quality was exceptional under all circumstances.

5 CONCLUSIONS

Antcor's Polling Optimizer is a proprietary technology that addresses the needs and requirements of modern wireless service providers. APOLLO's polling scheme manages to overcome the limitations of traditional WiFi technology. In addition, it's advanced Quality of Service architecture provides the necessary framework for supporting current and emerging broadband applications. With an enhanced feature-set, APOLLO offers a fast and easy migration path for WiFi-based service providers towards the wireless broadband market. The performance evaluation results indicate that APOLLO can achieve superior fairness and high network utilization under strict QoS constraints.

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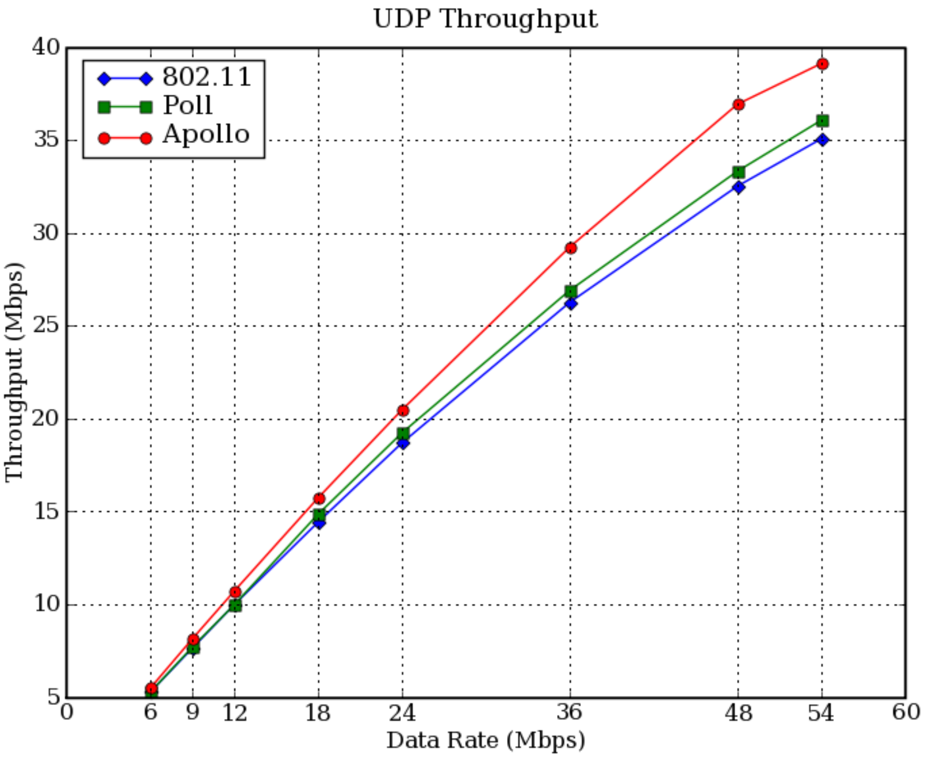

Fig. 3. UDP Throughput for variable data rates.

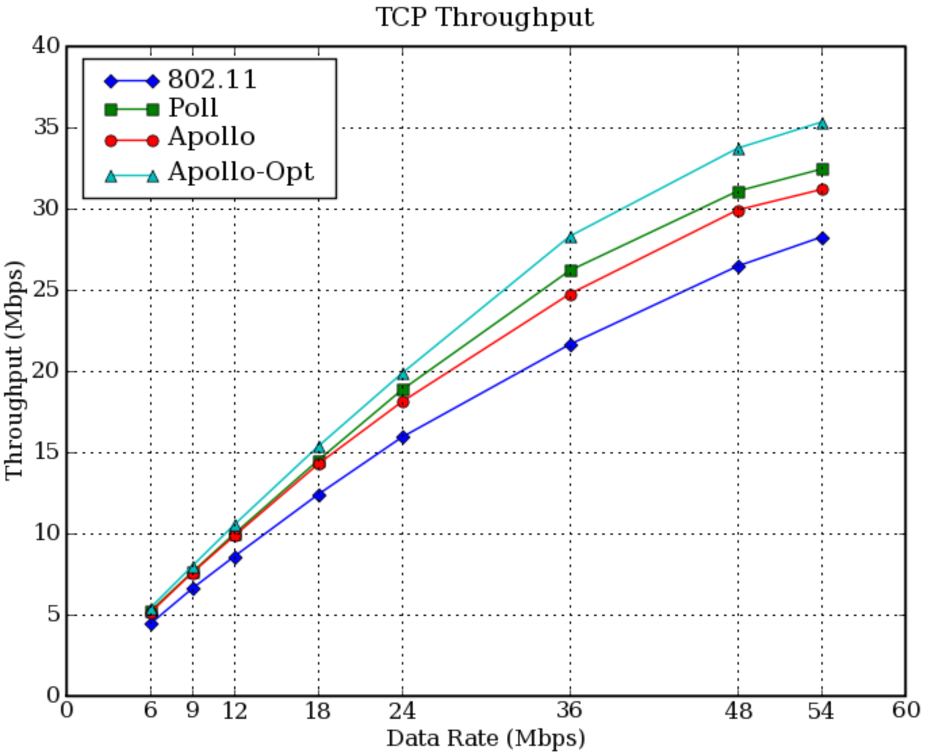

Fig. 4. TCP Throughput for variable data rates.

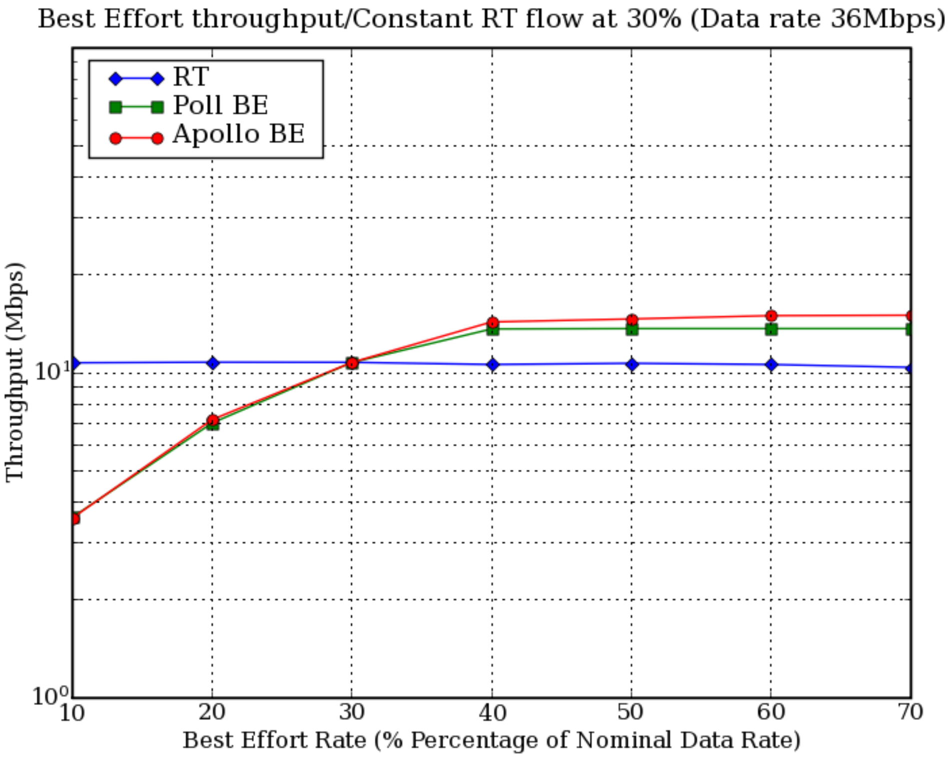

Fig. 5. Best Effort UDP Throughput with fixed RT flow.

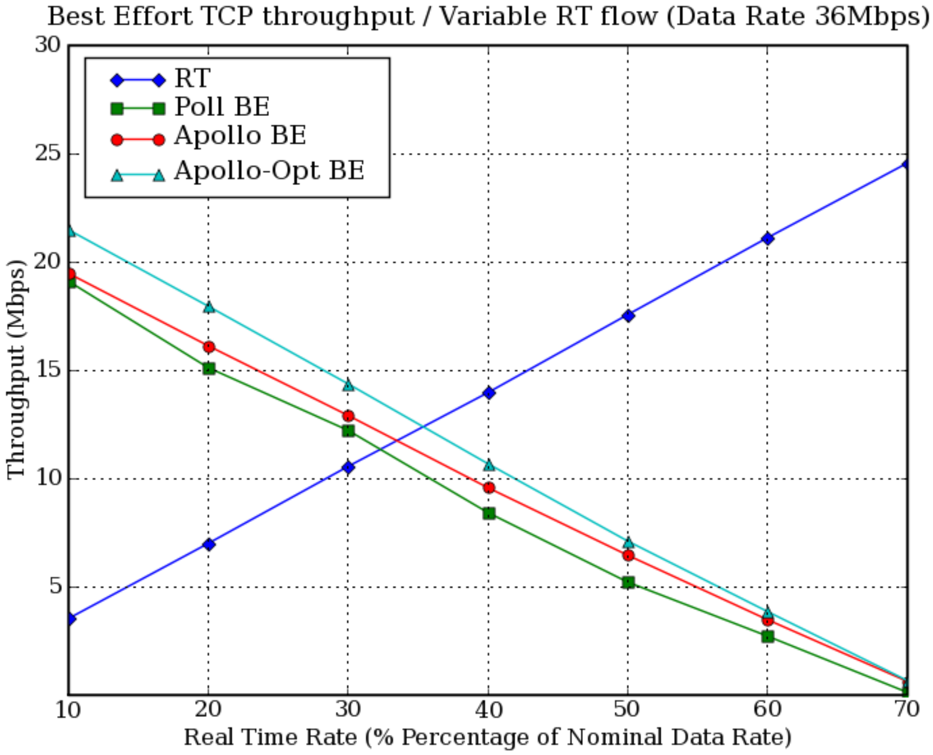

Fig. 6. Best Effort TCP Throughput with variable RT flow.

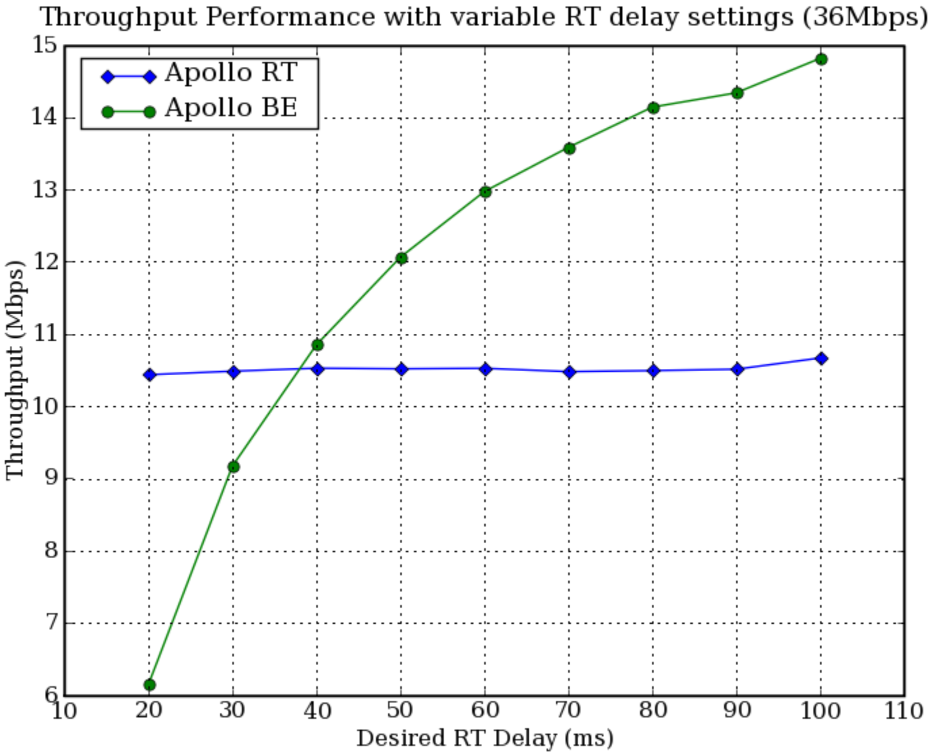

Fig. 7. Best Effort TCP throughput with different QoS constraints for worst-case Real Time delay (RT flow fixed at 30% of the nominal data rate).

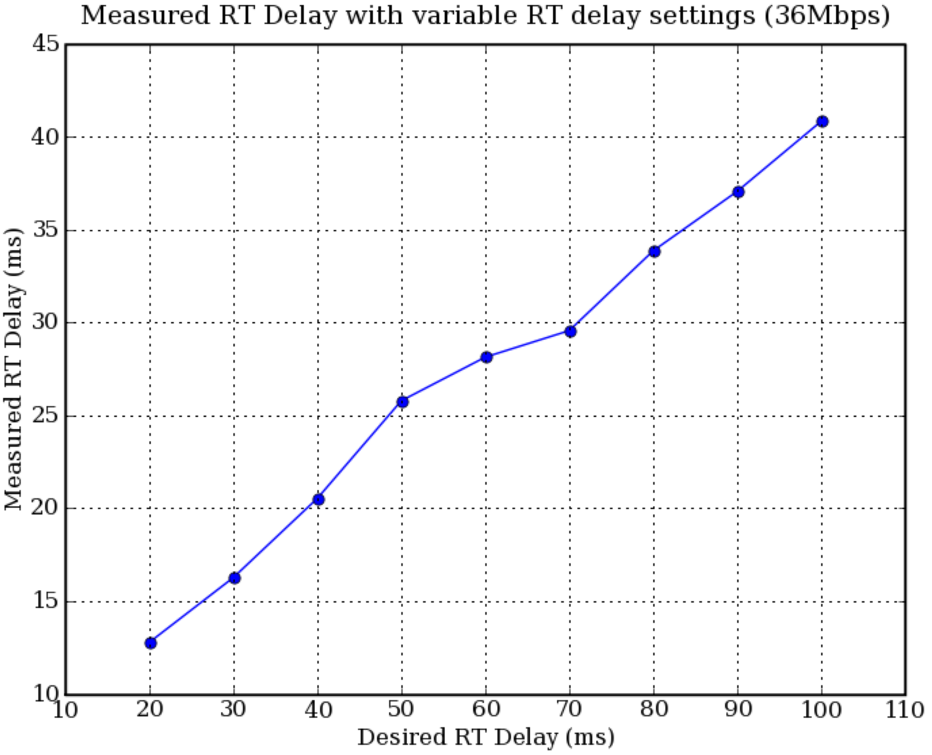

Fig. 8. Average RT delay for the scenario of Figure 7.

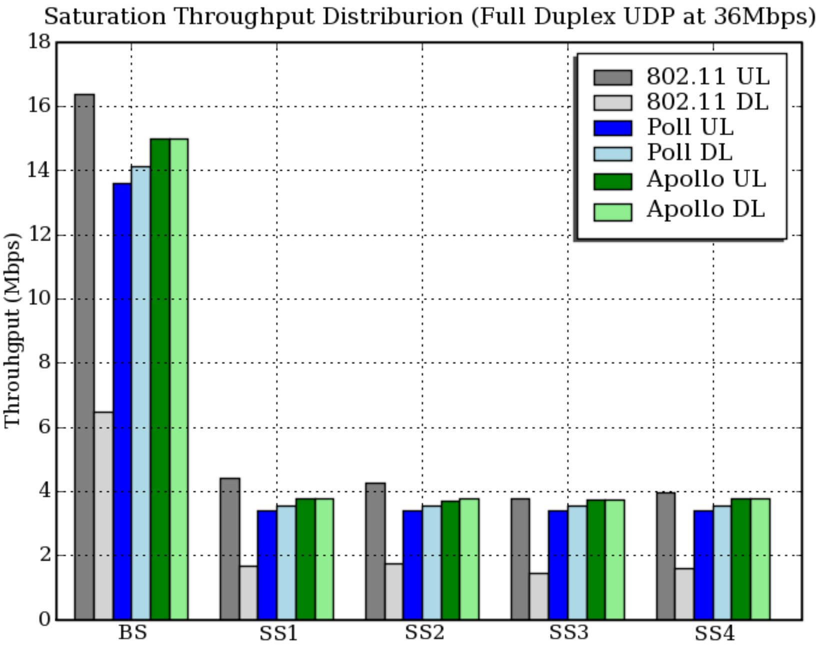

Fig. 9. Uplink (UL)/Downlink (DL) and inter-SS throughput distribution under UDP saturation.

🟩 Active: 64 🟧 Attempted : 0 Call Rate: 13/ Minute

	☑ Delay	☑ Jitter	☑ Loss	☐ MOS	☐ R Factor
Poor Value	41 ms	23 ms	0 %	4.4	92

	Total	Min	Max	Avg
SIP	0 KB	0 kbps	0 kbps	0 kbps
Skinny	0 KB	0 kbps	0 kbps	0 kbps
H.323	0 KB	0 kbps	0 kbps	0 kbps
Voice	328.9 MB	9.6 mbps	9.9 mbps	9.7 mbps
Others	223.1 MB	6.1 mbps	6.9 mbps	6.6 mbps

	Total (Packets)	Min (Packets/sec)	Max (Packets/sec)	Avg (Packets/sec)
SIP	0	0	0	0
Skinny	0	0	0	0
H.323	0	0	0	0
Voice	1,615,060	5,876.1	6,059.1	5,981.7
Others	241,124	821.8	948.9	893.1

Fig. 10. Snapshot of VoIP statistics report with 64 full-duplex concurrent calls.

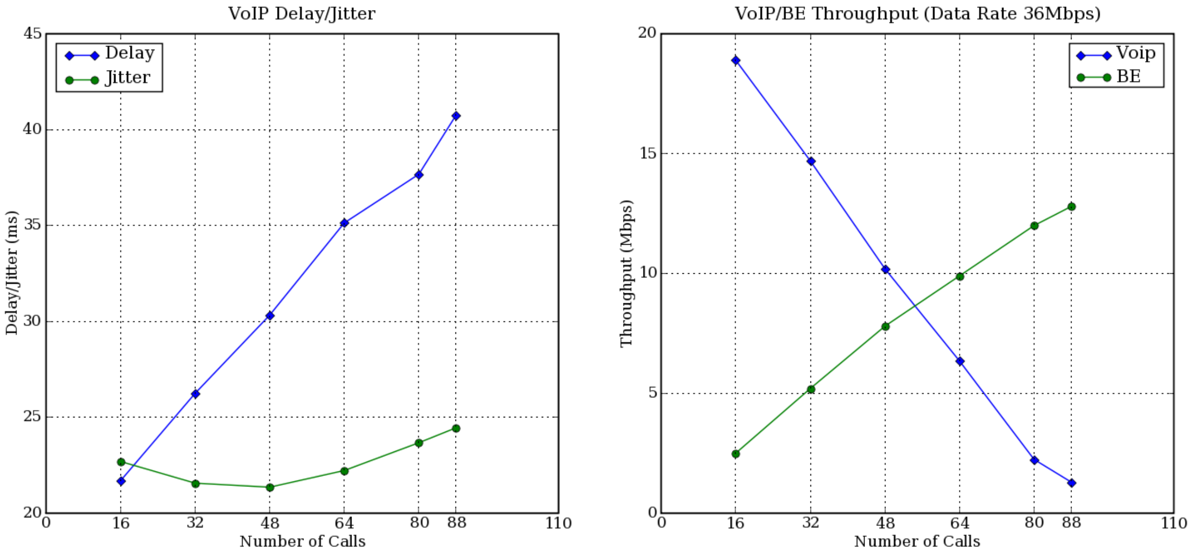

Fig. 11. Delay/Throughput for the 2-play WISP scenario.