Sensor-based Architecture for Quality-of-Service Support in WLANs

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Abstract

As Wireless Local Area Networks garner increasing interest from network access providers and customers, the ability to offer Quality-of-Service guarantees to multimedia applications remains an unresolved challenge. Limited bandwidth capacities and increasing traffic volume exacerbated by the need to maintain service quality in the presence of user mobility, entails radical rethinking of WLANs design. In this paper, we present a sensor-based resource management framework for QoS provisioning in WLANs, while retaining backward compatibility with existing implementations. We validate the efficiency of our design through theoretical analysis and demonstrate the benefits of our approach by simulations.

Keywords

Wireless Sensor Networks, WLAN, Quality-of-Service

1. Introduction

In satisfying the ever-growing need of roaming users, wireless LAN establishes itself as a leading access technology by providing "anywhere, anytime" connectivity. Flexible and easy to deploy, WLANs have been used in abundance across public areas (e.g. hotels, cafes, shopping malls, etc.) and at home. However, the limit of unlicensed frequency spectrum, compounded with environmental interference and access competition resulting from a multitude of transmission technologies are rendered the installment of QoS-assured applications impractical. Advancements in hardware technology have progressively increased the nominal throughput in WLAN to as high as 54Mbps (IEEE 802.11a [2]). In the near future, data rate is envisioned to exceed 100Mbps with new Standards (e.g. IEEE 802.11n [3] and IEEE 802.16 [4]). At the same time, spectrum regulatory institutions are trying to expand the unlicensed frequency band. These efforts will enable a wide area of multimedia applications, such as video streaming, gaming or delay-sensitive data applications (e.g. online auction).

Current resource management implementations in WLANs have focused on offering differentiated quality of service, based on the DiffServ approach initially developed for the Internet [5]. Priority levels can be enforced for instance by setting different waiting periods before accessing the medium (i.e. IEEE 802.11e). Some attempts have been made to provide hard QoS guarantees through polling mechanisms (i.e. Point Coordination Function defined in IEEE 802.11 Standard), but exhibited poor performance in real-world implementation due to significant bandwidth waste. Severe quality degradation can also occur during handoff if the delay involved in the reassociation process exceeds a certain threshold.

To address these challenging issues, we propose a novel architecture based on a wireless sensor network. We demonstrate that WLANs can significantly benefit from the specificities and capabilities of wireless sensor networks. Sensor nodes can improve network monitoring by retrieving accurate information on the surrounding environment and can communicate the results of the sensing operations to the mobile nodes or to the remote access point. They can also be used to deliver management and control packets between mobile nodes and access points without interfering with the data flow.

The remainder of this paper is organized as follows. The design of our architecture is described in Section 2. Section 3 gives details of our implementation. Simulations results are presented in Section 4. Section 5 concludes the paper.

2. Architecture Design

Our architecture augments the existing IEEE 802.11 access protocol with a low-capacity sensor network acting as a control plane. We assume that both networks operate on different channels.

Designing our architecture with a sensor network as a control plane presents multiple advantages. The ease-of-deployment of sensor nodes and their reduced cost favor their use in the context of WLANs. Besides, with their sensing capabilities, they can provide users with accurate information on the environment. They can be further used to deliver diverse information between mobile terminals and access points. Therefore, this low-capacity network can serve as an efficient control plane.

The topology of the control plane has to be designed in adequation with the characteristics of WLANs. The coverage area of the control plane should overlap the access points' transmission area in order to prevent the appearance of blind spots. The relay sensors network should also: (1) be dense enough to provide accurate information about the surrounding environment; and (2) prevent mobile nodes from suffering from long transmission delays by restricting their maximum number of hops N_{MaxHop}. Considering that the maximum transmission ranges of an access point and of a relay sensor are about 150m and 50m respectively, a hexagonal-lattice topology appears to be a sound approach ($N_{MaxHop} = 3$). However, our architecture is not constrained to this particular topology and other topologies can be envisioned.

3. Implementation

Our approach consists in offering mobile users the ability to reserve resources if desired. The general concept underlying our approach is as follows. A mobile node can request resource reservation from the access point by sending Resource Request messages, which contain information on the capabilities of the mobile node in terms of throughput and on the desired bandwidth. During a predetermined period, whose duration needs to be carefully dimensioned, the access point waits for the reception of such messages. Once the registration period is over, the access point establishes a schedule based on the received requests and transmits this information back to the concerned nodes in a Resource Notification message. The advantage of this mechanism is the dynamic set up of a resource scheduling based on the user's need instead of a fixed resource allocation that entails significant bandwidth wastage. Each mobile node can determine its bandwidth needs by monitoring its buffer occupancy at the application level.

Our scheme is based on a cyclic process, divided into two phases: the Scheduling Coordination Function (SCF) we introduce and the Distributed Coordination Function (DCF). Instead of implementing a fair scheduling algorithm whose obvious drawback is to ignore the specific needs of individual nodes, we propose an application-adaptive scheduling algorithm.

4. Evaluation

The efficiency of our architecture relies on a proper dimensioning of parameters including the registration duration , the transmission cycle duration and the control plane data rate. The simulation results can be used for such dimensioning. The benefits of our architecture for QoS provisioning are assessed by comparing our SCF to a traditional DCF for different types of traffic.

To assess the benefits of our architecture, we implemented different scenarios and analyzed for each case the average transmission delay and the number of bits transmitted. Our architecture, referred to as SCF in the figures, has been dimensioned with 80% of the transmission cycle for SCF and 20% for DCF. Note that alternative dimensioning can be used depending on how much the network designers want to prioritize multimedia traffic over best-effort traffic. In Figure 1 (a), we observe that the benefits of our architecture is significant whatever the number of multimedia users. The impact on voice traffic (Figure 1 (b)) is negligible as the traffic is sporadic and does not require as much bandwidth capacity as multimedia traffic (mainly video traffic). Note that voice and video traffic source characteristics are those provided in Qualnet (with 160-byte and 1280-byte packets generated respectively every 20ms and 1ms with a probability of 0.352 and 0.25 to model the traffic fluctuations). Simulations conducted to evaluate the performance of our architecture on the transmission delay showed a significant enhancement over DCF especially when the number of multimedia users increases. Our architecture also exhibits a more fair share of the medium utilization as reflected by the standard deviation.

5. Conclusion

Quality-of-Service remains a critical feature that current wireless LANs fail to provide. Although research efforts have been pushing towards the development of solutions based on differentiated quality of service, this approach is not satisfactory for time-sensitive applications.

In this paper, we proposed a novel architecture based on sensor networks. We addressed two major issues: resource reservation for QoS provisioning and mobility management. QoS provisioning can be efficiently and dynamically established on-demand, based on actual users' need. Mobile nodes can also benefit from a reduction of the hand-

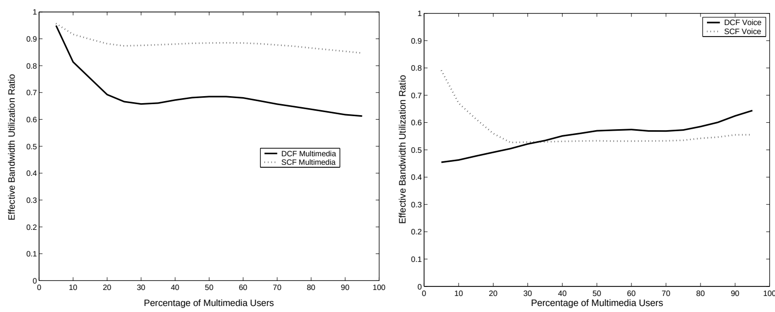

Figure 1: Effective bandwidth utilization ratio of (a) multimedia users (b) voice users

off delay by obtaining accurate information on the surrounding environment through the relay sensors. We demonstrated the effectiveness of our approach through theoretical validation as well as simulations.

The benefits of sensor networks for QoS management in WLANs is significant and it may be envisioned that the success of sensor networks would be important enough in the future to be able to use existing hardware for our architecture without extra deployment. A complete validation of our architecture would however necessitate a real implementation. It may also be interesting to estimate the cost of our solution in terms of energy consumption for the mobile nodes.

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