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# Performance evaluation of packet aggregation scheme for VoIP service in wireless multi-hop network ☆

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ABSTRACT

In a wireless multi-hop network environment, energy consumption of mobile nodes is an important factor for the performance evaluation of network life-time. In Voice over IP (VoIP) service, the redundant data size of a VoIP packet such as TCP/IP headers is much larger than the voice data size of a VoIP packet. Such an inefficient structure of VoIP packet causes heavy energy waste in mobile nodes. In order to alleviate the effect of VoIP packet transmission on energy consumption, a packet aggregation algorithm that transmits one large VoIP packet by combining multiple small VoIP packets has been studied. However, when excessively many VoIP packets are combined, it may cause deterioration of the QoS of VoIP service, especially for end-to-end delay. In this paper, we analyze the effect of the packet aggregation algorithm on both VoIP service quality and the energy consumption of mobile nodes in a wireless multi-hop environment. We build the cost function that describes the degree of trade-off between the QoS of VoIP services and the energy consumption of a mobile node. By using this cost function, we get the optimum number of VoIP packets to be combined in the packet aggregation scheme under various wireless channel conditions. We expect this study to contribute to providing guidance on balancing the QoS of VoIP service and energy consumption of a mobile node when the packet aggregation algorithm is applied to VoIP service in a wireless multi-hop networks.



## 1. Introduction

Wireless multi-hop network technology is receiving steady interest from academia and the industrial world since it can easily expand communication coverage with low cost by providing high connectivity between mobile nodes. In a wireless multi-hop network environment, mobile nodes acts as both source and destination nodes as well as relay nodes at the same time. So the mobile nodes may waste their energy for relaying data that just passes by the mobile node. The mobile node with discharged battery due to such energy consumption cannot act as a relay node any more, and this becomes a major cause of deterioration of network performance [1].

On the other hand, Voice over IP (VoIP) service that enables voice calls to be carried over the Internet has attracted attention because of the its potential for very low-cost or free voice calls [2]. VoIP service generates fixed sized packets periodically. The size of a VoIP packet is relatively small compared to other video or web packets, and the redundant header size of a VoIP packet is larger than the size of the payload including voice information. For example, VoIP Codec G.729 generates a 60 byte VoIP packet every 20 ms, that is composed of 40 bytes size of header information (IP-20 bytes, UDP-8 bytes, RTP-12 bytes) and 20 bytes size payload voice information. Hence when VoIP packet transmission occurs frequently in networks,

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eventually transmission overhead increases and the network bandwidth cannot be used efficiently.

In order to efficiently utilize bandwidth for VoIP service in wireless networks, research on packet aggregation algorithms has been employed. Packet aggregation is the process of joining multiple packets together into a single transmission unit in order to reduce the overhead associated with each transmission. Packet aggregation is categorized into two types: end-to-end and hop-by-hop aggregation algorithms. In case of end-to-end aggregation algorithm, packet assembly and disassembly are performed only in source and destination nodes, while an intermediate node acts as a router that just relays the aggregated packets. In case of hop-by-hop aggregation algorithm, packet assembly and disassembly can be performed in every node lying on the route between the source and destination nodes. Reduced overhead size in each transmission results in low energy consumption of a mobile node. However, as the size of an aggregated packet gets larger, the packet error rate and the end-to-end delay increase because of larger packet size and the additional queuing delay in a source node, respectively. Therefore, the number of VoIP packets to be combined into an aggregated VoIP packet is an important factor in determining the energy conservation of a mobile node and the QoS of VoIP service in a wireless multi-hop network.

The rest of this paper is organized as follows. Section 2 describes related works. In Sections 3 and 4, the *R*-factor which expresses the quality of VoIP service quantitatively and the energy consumption of mobile nodes are formulated, respectively, considering the size of an aggregated VoIP packet in a wireless multi-hop environment. In Section 5, we introduce a cost function denoting the trade-off relation between the QoS of a VoIP call and the energy consumption of the mobile node, and derive the optimum size of an aggregated VoIP packet from the cost function. In Section 6, we provide results and discuss their performances. Finally, the conclusion is given in Section 7.

## 2. Related works

The purpose of initial research on packet aggregation methods was to use bandwidth efficiently by reducing overhead in wired networks. Shaffer et al. [3] propose the packet aggregation methods for increasing the efficiency of data transfer in an Ethernet environment. Gopalakrishna [4] proposes packet aggregation methods to improve the utilization of the network bandwidth in an internet environment. Ketcham [5] proposes hop-by-hop packet aggregation methods to reduce the transmission time for real-time services and to improve the bandwidth utilization in packet based network. In recently, there have been many researches on the application of packet aggregation methods in wireless networks. When packet aggregation is employed in wireless networks, one should consider unstable wireless link quality and increased end-to-end delay, which are important factors to the QoS of (especially) real-time applications such as VoIP service. Also, the energy consumption of nodes is an important factor for the performance evaluation of packet aggregation algorithms in wireless environments. In the following subsections, we survey the effect of packet aggregation in wireless networks on the QoS of a VoIP service and the energy consumption of a wireless node.

### 2.1. QoS of VoIP service

Okech et al. [6] propose a link-based VoIP aggregation. Its performance improvement is compared with those of fixed packet aggregation under wireless mesh network. Simulation results show that the proposed packet aggregation scheme increases the number of supported flow while also reducing end-to-end delay, jitter, and packet loss of VoIP. Marwah and Singh [7] analyze the effect of packet aggregation on the quality of VoIP services in wireless mesh network, focusing on the packet aggregation delay and its effect to the end-to-end delay. Simulation results show that the use of packet aggregation is justified up to a certain end-to-end delay limit so as to avoid poor quality of VoIP services. Azevedo et al. [8] propose a new packet aggregation mechanism for real time applications over wireless network environments. The proposed algorithm considers a packet holding time estimation at which aggregation takes place and this estimation is used to allow for packet aggregation without degrading the QoS of VoIP service. Simulation results show that the proposed mechanism is capable of keeping jitter and end-to-end delay within application bounds.

### 2.2. Energy consumption

Marco et al. [9] present power measurements on IEEE 802.11b network cards. Specifically, they characterize the influence of packet size on total power consumption. Simulation results show that the packet aggregation mechanism yields substantial transmission power savings for workloads that frequently send small packets, such as Web workloads. Xu et al. [10] propose an adaptive waiting packet aggregation (AWPA) algorithm for energy efficiency and proper QoS for voice delivering in wireless sensor network. Simulation results show that proposed scheme has the advantages of both increasing goodput (the throughput perceived by the application) and conserving the energy consumption of mobile nodes. Palit et al. [11] propose the concept of a Low Energy Data-packet Aggregation Scheme (LEDAS). They evaluate the efficacy of LEDAS by simulations and show the energy-delay trade-off. Simulation results validate the efficacy of the scheme in terms of energy savings. Neander et al. [12] propose a flexible packet aggregation scheme which reduces the energy consumption of each device. Simulation results show that the proposed packet aggregation solution reduces energy consumption for a network by up to 50%.

In this paper, we analyze the effect of end-to-end packet aggregation algorithm in a wireless multi-hop environment considering *both* the QoS of VoIP service and the energy consumption of mobile nodes, simultaneously. Based on this analysis, we numerically prove trade-off between the QoS of VoIP service and the energy conservation of mobile nodes and suggest a cost function which is used to get the packet aggregation number optimizing the trade-off between the QoS and energy consumption.