On Multipath Balancing and Expanding for Wireless Multimedia Sensor Networks

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Abstract. Multiple disjointed paths have been demonstrated to be effective in delivering multimedia traffic in wireless sensor networks, and improving the network performance in terms of bandwidth aggregation, reliability and network lifetime. In this paper, we investigate the use of directional geographical routing for multipath construction for multimedia data dissemination, and identify the challenging issue of achieving multipath balancing in proximity to the source/sink. While our previous work addresses the multipath expanding problem efficiently, this paper presents a novel scheme to achieve the paths balancing distribution to alleviate the contention between the paths when close to the sink. The path construction is divided into expanding phase, parallel phase and converging phase in the proposed scheme, which includes two key algorithms, i.e., the detection algorithm for path construction phase and the deviation angle adjustment algorithm. Simulation results that verify the effectiveness of the proposed scheme are presented.

1 Introduction

Wireless sensor networks (WSNs) have attracted remarkable attention in the research community recently, driven by a wealth of theoretical and practical challenges and increasing number of practical civilian applications.

Recently, with emerging advances in sensor nodes which are capable of in-node image-processing [1], there is a growing interest in the design and development of multimedia sensor systems for applications in future wireless multimedia sensor networks (WMSNs) [2], such as advanced surveillance, security monitoring, emergency response, and environmental tracking, etc. However, it remains a challenging problem to deliver multimedia streaming data with the required QoS over WSNs [3] [4], due to the bandwidth limitation in such networks. Especially for video over WSNs, the compressed video bit stream is extremely sensitive to network dynamics. Our previous works [5] [6] address this issue by exploiting

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multiple disjoint paths to transmit multiple multimedia streams in parallel. In order to guarantee the requirements of aggregate bandwidth and fast packet delivery for multimedia traffic, we focus on multipath balancing and expanding at the source node. For example, the construction of multiple joint paths is divided into two phases in DGR [5]:

- *Multipath expanding*: The multiple paths are originated from a source node. In order to expand multiple paths evenly in a spatial distribution at the proximity of the source node, a series of initial deviation angles are specified for each individual path's construction. While a path is expanding in the specified direction, the initial deviation angle will be shrunk hop-by-hop to avoid the excessive expanding. Several heuristic based functions are suggested for deviation angle adjusting in [5].
- *Pointing back to the sink*: Typically, the deviation angle will be decreased to 0 after the path has been extended for a number of hops. Then, the path points back to the sink quickly through shortest path routing.

On the other hand, in a sensor network with a single sink at the center of the network, sensors around the sink need to relay every packet heading towards the sink. These sensors will quickly exhaust their energy in relaying traffic, which makes the network stop functioning as data packets cannot reach the sink. Since these sensors around the sink will be the network lifetime bottleneck, load-balancing is more important for the sensors at the proximity of the sink.

Though DGR achieves multipath expanding around a source node efficiently, the problem of multipath balancing around the sink node remains unsolved yet. Typically, the symmetric paths will form a heart-like shape, as shown in Fig. 1. The multiple disjointed paths will converge to a close proximity to each other when approaching to the sink node. Thus, there is still a lot of contention between the paths when close to the sink.

The main contribution of this paper is to enhance the original DGR algorithm, and the enhanced scheme is called E-DGR, which efficiently achieves the paths

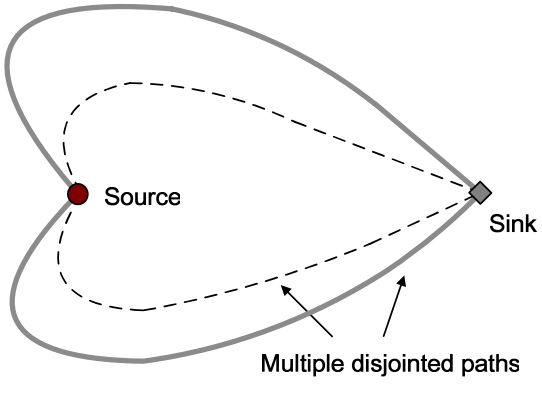

Fig. 1. Illustration of DGR's multipath construction

balancing distribution to alleviate the contention between the paths when close to the sink. Simulation shows that E-DGR exhibits better performance than the original DGR. It is expected that the higher performance improvement will be achieved when the application-specific path number is set to a large value.

The rest of this paper is organized as follows. Section 2 presents the related work. Section 3 describes the proposed algorithm for E-DGR. Simulation model and experimental results are presented in Section 4. Section 5 concludes this paper.

2 Related Works

In [2–4], three surveys on multimedia communication in WSNs have been well conducted. The authors analyzed and discussed the existing research works from both mobile multimedia and WSNs fields. These surveys showed that current existing protocols from the mobile multimedia and WSNs fields did not consider the characteristics of multimedia streaming data and natural constrains of WSNs at the same time. These papers also concluded that there exists a clear need for a great deal of research effort to focus on developing new efficient communication protocols and algorithms.

Many multipath routing protocols have been studied in the field of wireless ad hoc & sensor networks [9] [10]. However, most of the multipath routing protocols focus on energy efficiency, load balance, or fault tolerance in WSNs, and they are the extended versions of DSR [11] and AODV [12]. Only a few studies addressing time sensitive traffic transmissions over WMSNs. Due to the limited transmission capacity of sensor nodes, a single path often cannot meet the requirement of video transmissions. Consequently, multipath transmissions are needed. Chen *et al.* proposed DGR [5] to explore the application-specific number of node-disjoint routing paths to enlarge the aggregate bandwidth for the QoS provisioning in WMSNs. DGR is an algorithm designed specially for video sensor networks, and can greatly improve the performance in terms of lifetime and delay. It chooses the maximum number of paths from all found node-disjoint routing paths for maximizing multimedia streaming data transmission and guaranteeing the end-to-end transmission delay in WMSNs. Shu *et al.* proposed TPGF [6] [8] for geographical forwarding by taking into account both the requirements of real time multimedia transmission and the realistic characteristics of WMSNs. TPGF focuses on exploring the maximum number of optimal node-disjoint routing paths in the network layer in terms of minimizing the path length and the end-to-end transmission delay as well as taking the limited energy of WSNs into consideration. The TPGF routing algorithm finds one path per execution and can be executed repeatedly to find more node-disjoint routing paths.

3 Enhanced Directed Geographical Routing (E-DGR)

3.1 Directed Geographical Routing

DGR aims to compute multiple paths for a unicast video session. Fig. 2 illustrates an example of the construction of multiple disjointed paths by DGR [5]. In order