Incorporating User Willingness for Message Forwarding in Multi-Hop Content Distribution Scenarios

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I. Extended Abstract

Demands for video contents have significantly increased among the Internet users over the past years [1]. In this paper, we consider a video distribution scenario in a multi-hop wireless network. In this scenario, multiple nodes are interested in receiving a video content, available at a base station (or an access point) denoted by S. The video will be distributed in the network using a multi-hop broadcast scheme. In multi-hop broadcast, some nodes receive the data from S and forward it to others and this procedure continuous until all the nodes receive the video. In such scenarios, the network performance is highly influenced by the amount of energy that the nodes spend in the network for forwarding. The more energy a forwarding node spends, the more nodes could be served by it. More precisely, the performance of the network depends on the wireless devices which are controlled by users. The users usually have different preferences in contributing to the network in terms of energy consumption for forwarding. In this paper, the nodes which contribute more in the network are rewarded by a higher quality of the video than the other nodes. The goal of this paper is to minimize the total energy consumption in the network when the nodes have different willingness in forwarding videos.

The nodes in the network are divided into two categories based on their preferences in contributing in terms of energy for forwarding a video. The two categories are for the nodes with low willingness and high willingness to forward videos which are denoted by LWF and HWF, respectively. In order to provide a high quality video to the HWF nodes, the use of the scalable video coding (SVC) [2] is proposed. videos coded by SVC are composed of several layers: a base layer which results in a basic video quality and several enhancement layers. The more enhancement layers a node can receive, the higher is the quality of received video. In this network, a basic video quality (SD) will be provided for the LWF nodes while HWF nodes receive high video quality (HD). In other words, receiving a high quality video can be seen as a kind of reward for the nodes who contribute more in the network.

In this network, the nodes of each category have a specific transmit power constraint and consequently a limited coverage

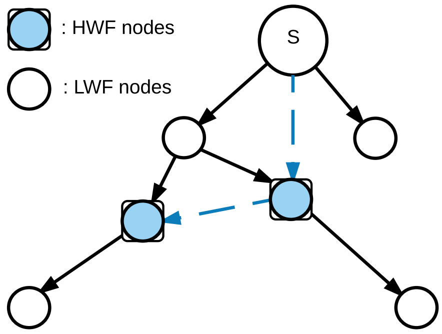

Fig. 1: A network with 4 LWF nodes and 3 HWF nodes. Black arrows show the broadcast tree by which the SD video is transmitted. The dashed arrows represents the broadcast tree for HD video distribution among the HWF nodes.

area. Considering the transmit power constraint of a node j, the nodes which are inside the coverage area of node j are called its neighboring nodes. A node j that forwards the video to others is called a parent node for its respective receivers. The nodes which receive the video from a parent node j are called the child nodes of parent node j. Every child node could be a parent node for other nodes and the source node is always a parent node. Note that a parent node may have multiple child nodes and transmit the video to them at once in a multicast transmission while a child node just can have one parent node. The connection between a parent node and its child nodes in the whole network results in a tree graph, called broadcast tree. The broadcast tree determines how the video is distributed in the network. An illustrative network model is shown in Fig. 1.

Considering the SVC coding which is composed of separated layers, we propose using two broadcast trees. The first broadcast tree which involves all the nodes of the network is for distributing the SD video and the second one disseminates the additional layer for HWF nodes so that they can receive the HD video. There are different approaches in constructing a broadcast tree [3] [4]. We use a game theoretical model as a decentralized algorithm in broadcast tree construction. The goal of the game is to obtain a broadcast tree which minimizes the energy consumption in the whole network. The

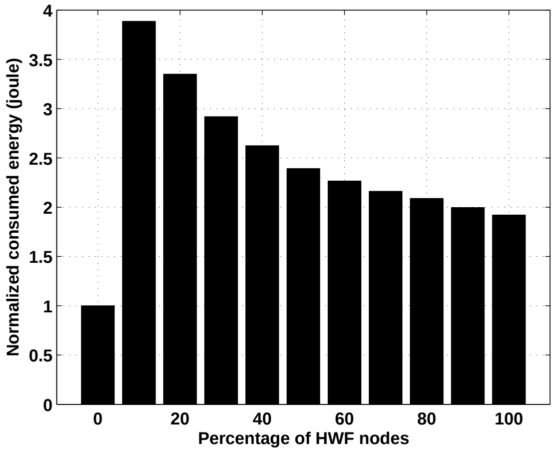

Fig. 2: Total energy consumed in the network normalized to the case that only the SD video is distributed.

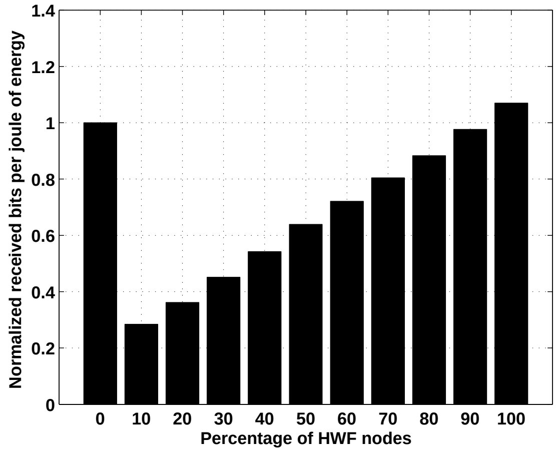

Fig. 3: Efficiency of the algorithm in terms of bits delivered to the nodes per each joule of consumed energy. The result is normalized to the case that only the SD video is distributed.

players of the game for the first broadcast tree construction game which distributes the SD quality are all the nodes of the network, while for constructing the second broadcast tree, just HWF nodes are the players. We assume that the players of each game, i.e., the LWF nodes and HWF nodes, are known based on their preferences before the game begins. The action of a node in this game is to choose one of the nodes in its neighborhood as its parent node. Based on the action of the nodes in the network, a cost will be assigned to the node. The game is non-cooperative and in an iterative procedure the node chooses its best parent node. We use the Nash Equilibrium as the solution concept of our game and show that our proposed game converges to this point after some iterations. The formal definition of the game including the cost definition and decision making of the nodes will be presented in the complete version of the paper.

For simulating the network, a square region with the size of 500 m $\times$ 500 m is assumed in which 60 nodes are randomly distributed. The channel bandwidth is set to 20 MHz and a path-loss model is considered for the channel. We assume that the channels are orthogonal and there is no interference between data transmitted by different transmitters at a given receiver. The required data rate for the SD and the HD videos are set to 0.9 Mbps and 1.85 Mbps, respectively. we assume that a LWF node is able to provide the SD video in circular coverage area around itself with the diameter of 100 m. The coverage area for the HWF nodes is set to 200 m and every HWF node is able to forward the additional necessary layers for HD videos to another HWF node its coverage area.

In Fig. 2 the total energy consumed in the network for distributing the SD and the HD videos are shown as a function of the percentage of HWF nodes in the network. The result is normalized to the case that there is no HWF node in the network and just the SD video quality is disseminated. As it can be seen, when there are HWF nodes in the network, the energy consumption in the network increases as a higher data rate must be delivered to the receiving nodes. By increasing the number of HWF nodes in the network, since the distance between the nodes reduces and more neighboring nodes would be available for every node, a more efficient broadcast tree can be built among the HWF nodes. When all the nodes are HWF, the required energy for transmitting HD video to all nodes is less than twice the energy required to transmit the SD video.

Fig. 3 Shows how efficient the energy is consumed in the network. More precisely, it shows how many bits can be disseminated by spending one Joul in the network. The result is normalized to the case that only the SD video is disseminated. SD video requires low amount of energy while lower data rate is distributed in the network. When by increasing the number of HWF nodes, not only the number of nodes who receive high data rate increases, but also as shown in Fig. 2, less energy is required for HD video distribution. Therefore the efficiency in the network increases. In a network in which all the nodes are HWF, the energy can be utilized the best.

Considering both Fig. 2 and Fig. 3, we observe that having more HWF nodes in the network is not only result in high video quality for the nodes, but also the resources in the network can be utilized in a more efficient way. Therefore in designing markets and networks, motivating the nodes to receive HD videos in the cost of forwarding more in the network would be both beneficial for network and the users.

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