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LINEAR NETWORK CODING FOR MINIMUM-ENERGY WIRELESS MULTICAST NETWORK

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Abstract - Conventional routing ways of wireless multicast advantage application in reduce energy consumption is generally used to establish a "minimum-energy multicast tree" to achieve the minimum energy multicast. However, the problem of constructing a minimum-energy multicast tree in a wireless ad hoc network is NP-hard. By using network coding, this problem is transformed into linear or convex programming problem. In this paper, we adopt the description of minimum-energy multicast at last and get a random linear network coding model based on wireless multicast advantage to achieve the minimum-energy multicast. Thus, it can get a better information flow distribution, and the energy consumption of each bit under the layered model is minimized.

Keywords - Random Linear Network Coding; Minimum-Energy Multicast; Wireless Multicast Advantage.

I. Introduction

Conventional routing ways of wireless multicast advantage application in reduce energy consumption is generally used to establish a "minimum-energy multicast tree" to achieve the minimum energy multicast. However, the problem of constructing a minimum-energy multicast tree in a wireless ad hoc network is NP-hard [1]. By using network coding, this problem is transformed into linear or convex programming problem. Network coding was first introduced in paper [2] by Dr. Ahlswede and Caining et al. from information theory perspective in 2000. It is based on a simple idea where allows the intermediate nodes of the communication networks to code the information they received from their incoming links. Then at the sinks, information is retrieved from what they received. Network coding has absolutely caused the changes of the traditional information operation method in computer networks and it can enhance the capacity of the communication networks.

After that, Li et al. [3] show that linear coding can be used for multicasting with rate and prove that linear coding suffices to achieve the optimum, which is the max-flow from the source to each receiving node. Tracey Ho [4] presented a distributed random linear network coding approach for transmission and compression of information in general multi-source multicast networks, which don't have to get the network topology structure and don't have to verify it. And they also analysis the success probability and robustness about the Random linear network coding. After that, random linear network coding is applied to all aspects of research, to improve network throughput and energy efficiency.

The unreliability of the wireless link and the broadcast characteristic of physical layer make network coding in energy efficiency having a wide application, and providing a new way for minimum-energy broadcast. Wu et al [5,6]. shown that under a layered model of wireless networks, the minimum energy per-bit for multicasting in a mobile ad hoc network can be found by a linear program; the minimum energy-per-bit can be attained by performing network coding. And they proposed a solution under the mobile ad hoc network to the minimum-energy multicast. Lun et al [7, 8].

Presented decentralized algorithms that compute minimum-cost sub graphs for establishing multicast connections in networks that use coding. And they proposed a fixed topology wireless multicast network coding solution to minimum-energy multicast. Katti et al.

[9] proposed COPE, a new architecture for wireless mesh networks. They evaluate their design on a 20-node wireless network, and discuss the results of the first test platform deployment of wireless network coding. Running the tested on 802.11a. This implies that the total number of transmissions in the network can be reduced significantly.

In this paper, taking into account the wireless multicast advantage, we transform the method proposed in [10] to achieve the minimum-energy multicast. Compared to the linear network coding using in minimum-energy in [10] random network coding better applied to the actual network. It can use the remaining capacity of the entire network to obtain the optimal network capacity and improve the robustness of the multicast network. And we can better find the appropriate capacity graph G, and its information flow distribution. Thu0s, the energy consumption in the multicast transmission is minimized. Not only reached the maximum capacity of the network, but also effectively reduced the network resource consumption.

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II. The Basic Principles Of Random Linear Network Coding

The core idea of the random linear network is to use the node's computing power--the sending node using linear combination to get different information encoded packet, the receivers need know the overall linear combination of source processes in each of their incoming transmissions, thus, it can obtain the original packet by computing. The following gives a simple model of random network coding [11].

A. The basic model:

We adopt the model of [11], which represents a network as a acyclic delay-free graph G=G(V,E), All edges are unit-capacity, Discrete independent random processes $X(v,l), l \in \{1,2, \mu(v)\}$ are observable at one or more source nodes. And it has the same constant entropy rate of one bit per unit time. T∈ E is the set of destination nodes, R is the maximum capacity. The output processes at a receiver node β are denoted $Z(\beta, i)$

There are v links in the network. Link e is *an incident outgoing link* of node v if v = tail(e), and *an incident incoming link* of v if v = head(e). We call an incident outgoing link of a source node *a source link* and an incident incoming link of a receiver node *a terminal link*. Edge e carries the random process $Y(e)$. So we call the G is the linear network. For a linear code, the signal $Y(e)$ on a link e is a linear combination of processes $X(v,l)$ generated at source node and signals $Y(e')$ on incident incoming links e' . For the delay-free case, this is represented by the equation

	$\mu(v)$		
$Y(e) =$	$\alpha_{e,l} X(v,l)$ +		$\beta_{e',e} Y(e')$(2-1)
	l=1	e':*head* (e')=*tail*(e)	

And an output process $Z(v, i)$ at receiver node v is a linear combination of signals on its terminal links,

$$\frac{B_1}{B} = \overline{B_d}$$

represented as			
$Z(v,i)$ =		$\varepsilon_{e,i} Y(e)$	(2-2)
	{e:*head*(e)=*tail*(e)}		

The coefficients $\{\alpha_{e,l}, \beta_{e',e}, \varepsilon_{l,e}\}$ can be called the local coding vector, which are independently and random treated as elements of a finite field F^{2m} .

The coefficients $\{\alpha_{e,l}, \beta_{e',e}, \varepsilon_{l,e}\}$ can be collected into $r^{\llcorner}$

$Y^{\llcorner}$ matrices A = $(\alpha_{e,l})$ and $B_\beta = (\varepsilon_{l,e})$, and the $v^{\llcorner}$ Y matrix F = $(\beta_{e',e})$, whose structure is constrained by the network. For acyclic graphs, we number the links ancestrally, i.e. lower-numbered links upstream of higher-numbered links, so matrix F is upper triangular with zeros on the diagonal. A triple (A, F, B), where

$$\frac{B_1}{B} = \overline{B_d}$$

specifies the behaviour of the network, and represents a linear network code.

Matrix $A(I - F)^{-1}$ gives the transfer matrix from input processes to signals on each link; the connection problem is feasible if and only if $A(I - F)^{-1} B_\beta^T$ has full rank for each receiver [12].

When a random network coding used in multicast networks, multiple sources can be linearly independent or linearly related. It can compress the information. In addition, random network coding better applied to the actual network compared to linear network coding. It can use the remaining capacity of the entire network to obtain the optimal network capacity and improve the robustness of the multicast network.

Consider the example of distributed random linear network coding shown in Fig. 1. *X1* and *X2* are the source processes being multicast to the receivers *T1* and *T2*. The relay node A, B, C and D randomly choose the coefficients ξ_i elements of a finite field. The label on each link represents the process being transmitted on the link.

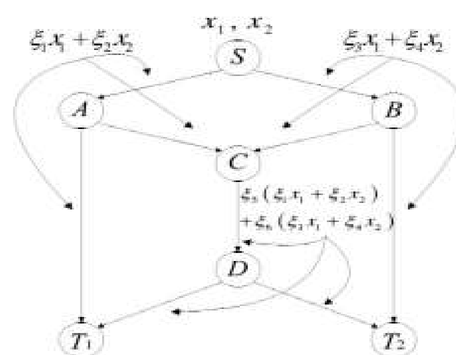

Fig.1. the random linear network coding

The Description Of The Minimum-Energy Multicast Based On Wireless Multicast Advantage

Minimum-energy multicast is a wireless multicast advantage application in reduce energy consumption, its implementation involves power control and scheduling in the physical layer and media access layer, and routing algorithm or network coding in network layer. In order to achieve optimal performance, we need cross-layer design