Cooperative Multicast Transmission Strategy for Energy-Efficient Dynamic Network Coding

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Outline

- Background
- My Work
- Conclusion
Background

- Reducing energy consumption has drawn much attention in wireless multicast services.
- Previous work to achieve the energy efficient communication
  - Network coding
    - recombines several input packets into a combined version for forwarding
    - reduces the retransmission times
  - Cooperation communication
    - copes with error-prone and unstable characteristics of wireless channels’ conditions from the BS to users
  - Relay selection
    - Selects considerable number of relays in the 1st stage of the two-stage cooperation
    - Reduces energy consumption with power control
My work

• In this paper:
  – Apply network coding to the relays in 1\textsuperscript{st} stage of the two-stage cooperation.
    • Saves the retransmission times
    • Reduces the energy consumption for this time
  – Two network coding strategy will be investigated
    • XOR-network coding, applying xor operation to two packets,
    • Dynamic network coding, selecting coefficients of the packets from the Galois Field($q$)
  – Defined the waiting time cost
    • Trade off between the waiting time for the users in the second stage and the energy saved for the communication system
    • The relay users can decide when to stop accumulating the packets from BS and enter the second stage
My Work--System Model

• The BS multicasts $q$ different data on the row to the entire users with a high rate $S_i$. The $q$ selects from Galois Field ($q$).

• According to the principle that the closer to the users, the better transmission quality will be gained from the channel, the users in $U_s$ who are closer to the users in $U_F$ are likely to be chosen as the relays.

• In 2nd stage, selected relay users deliver packets to the users in $U_F$.

Fig. 1
My Work--Network Coding Strategy

- For the first stage, $T_1$ stands for the time duration of BS transmitting packets to all the users.
- $t_1$ stands for the time duration of BS transmitting one packet to the entire users.
- As for the second stage, $T_2$ stands for the time duration of users in $U_S$ transmitting the packet(s) to the users in $U_F$.

Fig. 2
## My Work—XOR-Network Coding

### Tab. 1 Receiving State of the users $U_F$

<table>
<thead>
<tr>
<th>Pattern 1</th>
<th>Pattern 2</th>
<th>Pattern 3</th>
<th>Pattern 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>User A</td>
<td>1</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>User B</td>
<td>1</td>
<td>X</td>
<td>2</td>
</tr>
</tbody>
</table>

\[
1 \oplus 1 = 2 \quad 1 \oplus 2 \oplus 1 = 2 \quad (1 \oplus 2) \oplus (1 \oplus 2) = 0!!!
\]

\[
1 \oplus 2 \oplus 2 = 1
\]

Assume that the four patterns in Tab.1 are independent and identically distributed:

\[
\text{retransmission times} = \frac{1}{4} \times (1+1+1) + \frac{1}{4} \times 2 = \frac{5}{4}
\]

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What can we do with pattern 4?

\[
\begin{bmatrix} X \end{bmatrix} \begin{bmatrix} 1 \\ 2 \end{bmatrix} = \begin{bmatrix} Y \end{bmatrix} \quad (1)
\]

\[
\begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} \begin{bmatrix} 1 \\ 2 \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} \quad (2)
\]

Dynamic network coding!!!

- Since relay users shall also broadcast the packets, one user in \( U_F \) would received the packets transmitted from several relay users, those packets form the matrix \( Y \).
- Obviously, by applying dynamic network coding, the number of retransmitting packet(s) in stage II is reduced to 1.
My work—Waiting time cost

- However, if $q$ is infinite, users in $U_F$ have to wait for a quite long time.
- Trade off between the time and saved energy.
- Define the waiting time cost, relay users decide when to stop accumulating the packets from BS and enter the second stage.
My Work—STPEC

- Energy consumption:

\[ EC = P_{bs} \cdot T_1 + P_{ue} \cdot T_2 \]  \hspace{1cm} (1)

- System throughput:

\[ ST = \frac{1}{T} (P_s \cdot S_1 \cdot T_1 + S_2 \cdot T_2 \cdot M) \]  \hspace{1cm} (2)

- Transmi power of BS
- Transmit power of relay
- Successfully receiving probability of the first stage
- The number of relays participating in stage II according to min-SNR principle

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Simulation Results

• With the number of the users mounting, the energy consumption is increasing.

• This is because that more users in $U_F$ need adding and more energy is spent on the relay users in the second stage.

• Obviously ESS-XOR outperforms the ESS. Because of the pattern 4, the gap is not very big. However, pattern has no influence on ESS-DNC, which has the best performance of the three schemes.

Fig. 4 Normalized Energy Consumption for ESS, ESS-XOR and ESS-DNC with $q = 4$. 
Simulation Results

- With the number of users increasing, the gain is firstly increasing and when the number of user is approximately 60 the gain is decreasing.
- This is because that when the number of users mounting, more users belong to $U_F$, and more relay users and energy are needed to help the users in $U_F$.
- Compared with ESS, the ESS-XOR has significantly improved the system throughput per energy consumption. Moreover, the ESS-DNC also has better performance than ESS-XOR.

![Graph showing system throughput per energy consumption gain for ESS-XOR, ESS-DNC with $q = 4$ and $q = 8$.]
Fig. 6 shows how the value $q$ influences the STPEC (System throughput per energy consumption).

With the number of users fixed, the increasing of $q$ can make the energy more efficient for one transmission contains more information.
Simulation Results

- Fig. 7 presents the time waiting cost is increasing when $q$ is mounting.
- This is because that in order to applying dynamic network coding to the received packets, the relay users have to accumulate more packets by extending $T_l$.
- However, according to the given waiting time cost, the relay users could determine when to stop waiting and enter the second stage and the corresponding $q$ can also be decided.

![Fig. 7 The standardized waiting time cost for different $q$](image)
Conclusion

- This paper
  - By applying xor-network coding to the two-stage cooperation, the retransmission times can be reduced to 5/4.
  - By applying dynamic network coding to the two-stage cooperation, the retransmission times can be reduced to 1.
  - By defining waiting time cost, the relay users can trade off between the saved energy of the system and the waiting time for the users in the second stage.
  - The energy consumption decreases as the retransmission times be reduced.
  - Energy efficient communication is achieved by using the network coding strategy in the two-stage cooperative scheme.
THANK YOU!
Q&A?