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Cooperative Packet Delivery in Wireless Networks

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ABSTRACT: The cooperative communication represents the cooperation among the nodes which are participating in communications. It also achieves higher bandwidth efficiency while guaranteeing the same diversity order as that of the conventional cooperative schemes. These schemes discuss the relay selection via available partial channel state information (CSI) at the source and the relay nodes. Few of the methods behind the cooperative communications are considered in this proposed work. Some of the methods such as Pure Cooperative Communication, Triple busy tone Multiple Access Mechanism, and Node Selection Algorithm, determine the relay nodes which are in the belonging to the network when the source node transmits the message or information to destination node.

KEYWORDS: symbol error rate, cross layer triple busy tone multiple access, cooperation node

I. INTRODUCTION

Multi path fading is one of the major obstacles for the next generation wireless networks, which require high bandwidth efficiency services. Time, frequency, and spatial diversity techniques are used to mitigate the fading phenomenon. Recently, cooperative communications for wireless networks have gained much interest due to its ability to mitigate fading in wireless networks through achieving spatial diversity, while resolving the difficulties of installing multiple antennas on small communication terminals. In cooperative communication, a number of relay nodes are assigned to help a source to forwarding its message or information to the desired destination.

II. RELATED WORK

Various cooperative diversity protocols were analyzed. Laneman *et al.[2]* described various techniques of cooperative communication, such as decode and-forward, amplify-and-forward, selection relaying, and incremental relaying. It was shown that the first two schemes achieve bandwidth efficiency equal to 1/2 symbols per channel use (SPCU), while the other two schemes achieve higher bandwidth efficiency. The [3], distributed space-time coded (STC) cooperative scheme was proposed, where the relays decode the received symbols from the source and utilize a distributed space-time code. Su *et al.* derived symbol error rate (SER) for single-relay decode-and-forward and amplify-and forward cooperative techniques in [4] and [5], respectively. In [6], Sadek *et al.* provided SER performance analysis for the decode-and-forward multi-node schemes.

There are various protocols proposed to choose the best relay among a collection of available relays in the literature. In [7], the authors proposed to choose the best relay depending on its geographic position, based on the geographic random forwarding (GeRaF) protocol proposed in [8] and [9]. In GeRaF, the source broadcasts its data to a collection of nodes and the node that is closest to the destination is chosen in a distributed manner to forward the source's data to the destination. In [10], the authors considered a best-select relay scheme in which only the relay, which has received the transmitted data from the source correctly and has the highest mean signal-to-noise ratio (SNR) to the destination node, is chosen to forward the source's data. In [11], a relay-selection scheme for single relay decode-and-forward cooperative systems was proposed. In this scheme, the source decides whether to employ the relay nodes in forwarding its information or not, depending on the instantaneous values of the source-destination and source-relay channels gain.

III. PURE-COOPERATIVE COMMUNICATION

When the SINR of the received corrupted packet *x_* is below the given threshold Λ*th*, the requirement of HCNC cannot be satisfied. [1]

Therefore, P-CC is employed in which the packets queuing in the relay node cannot be served during the retransmission process. Upon receiving the NACK with SINR FLAG equal to 0, each relay candidate contends for the relay node using a utility based back off time given by

$$Tu_i^P = \frac{\tau}{\beta \cdot (S_{ij} / S^{max}) + d^{min} / d_i},$$

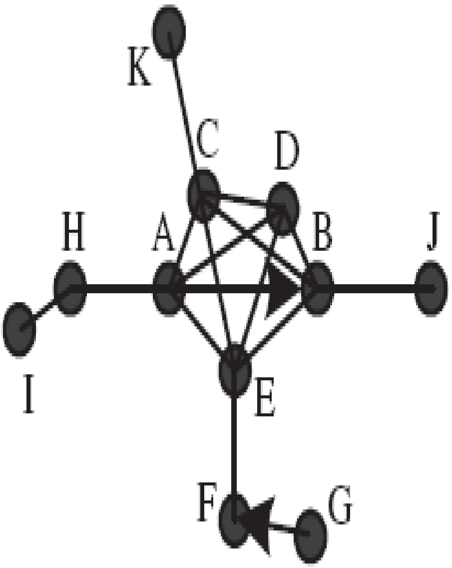

Fig. 1. A simple network for cooperation

where *di* is the estimated delay at node *i*, and *dmin* is the lower bound of the estimated delay. Since the relay node postpones all the packets queuing in its buffer when it serves the source node in P-CC, the node with high estimated throughput and short estimated delay will be selected as the relay node. The estimated delay of a given relay candidate not only depends on the number of the packets queuing in its buffer, but also is related to the individual data rates of those packets and the particular node density. The expected average delay at relay node *i* is expressed as

$$d_i = \sum_{y=1}^{L_i} E_{iD(y)}^{R_{iD(y)}}(MAC) + E_i^{R_{ij}}(RET),$$

where *y* is the queuing packets at relay node *i* (from 1 to*Li*), $E_{iD(y)}^{R\,iD(y)}$ (*MAC*) is the expected average MAC delay for a transmission of packet *y* from node *i* to node *D*(*y*) with data rate $R_{iD(y)}$, E^{Rij}_{i} (*RET*) is the additional delay for retransmitting the packet on behalf of the source node. *ERij i* (*RET*) can be regarded as a constant to all the relay candidates. It is Calculated as where δ is the maximum propagation delay.[2]

$$E_i^{R_{ij}}(RET) = T(ETH) + T_i^{R_{ij}}(DAT) + T(ACK) + 2SIFS + 3\delta,$$

Notice that *di* is lower bounded by the minimum estimated delay *dmin* when there is no queuing packet at node *i*. *dmin* is equal to $E^{R_{ij}}{}_{i}$ (*RET*). As shown in Fig. 5, when the packet arrives, if the surrounding medium is idle for DIFS, node *i* enters into the *backoff* state, otherwise, it enters into the *f*reeze state. Thus, the excepted average MAC delay of a transmission can be expressed as the summation of two parts as

$$\begin{aligned} E_{iD(y)}^{R_{iD(y)}}(MAC) &= \mathcal{P}_i(AB)\cdot(DIFS + E_{iD(y)}^{R_{iD(y)}}(BAK)) \\ &\quad + \mathcal{P}_i(AF)\cdot(DIFS + E_{iD(y)}^{R_{iD(y)}}(FRZ)), \end{aligned}$$

where $E^{RiD(y)}{}_{iD(y)}$ (*BAK*) is the estimated time consumed in back off state, $E^{RiD(y)}{}_{iD(y)}$ (*FRZ*) is the additional delay accumulated in freeze state. P*i*(*AB*) and P*i*(*AF*) are the probabilities of state transition from arrival to back off and from arrival to freeze, respectively. To formulate the estimated delay, we should consider the randomness of both packet arrival rate and service time. Using the most common description of Poisson statistics, the probability of exactly *n* packets arriving during time interval

$$p^n(t) = \frac{(\lambda t)^n}{n!}e^{-\lambda t},$$

Where λ is the mean packet arrival rate. Hence, the probability of channel is idle for time interval *t* can be derived by

$$p_i^{idle}(t) = e^{-\lambda(i)t},$$

where λ(*i*) is the total packet arrival rates within the transmission range at node *i*. λ(*i*) is equal to |*NBi*| · λ, where |*NBi*| is the number of neighbors of node *i*. Using *piddle i* (*t*), P*i*(*AB*) and P*i*(*AF*) in Eqn. (9) can be easily expressed as

$$\mathcal{P}_i(AB) = p_i^{idle}(DIFS) = e^{-\lambda(i)DIFS}.$$

$$\mathcal{P}_i(AF) = 1 - \mathcal{P}_i(AB) = 1 - e^{-\lambda(i)DIFS}.$$

The average random back off time *B* in Eqn.

$$E_{iD(y)}^{R_{iD(y)}}(BAK) = T_i^{R_{iD(y)}}(DAT) + T(ACK) + SIFS + 2\delta + \overline{B}.$$

where η is the time slot, *Wmin* is the minimum back off window size and *N* equal to log2 (*Wmax*/*Wmin*). Notice that in Eqn. (14) we use an optimistic estimation for the transmission time based on the assumption that no retransmission occurs.[3] On the other hand, the accumulated delay in freeze state $E^{RiD(y)}{}_{iD(y)}$ (*FRZ*) is

$$\begin{aligned} E_{iD(y)}^{R_{iD(y)}}(FRZ) &= \mathcal{P}_i(FF)\cdot(DIFS + E_{iD(y)}^{R_{iD(y)}}(FRZ)) \\ &\quad + \mathcal{P}_i(FB)\cdot(DIFS + E_{iD(y)}^{R_{iD(y)}}(BAK)), \end{aligned}$$

where P*i*(*FF*) and P*i*(*FB*) denote the probabilities of staying in freeze state and transmitting from freeze state to back off state, respectively.[4] These probabilities are calculated by
$P_i(FB)=e^{-\lambda}(i)DIFS$ and $P_i(FF) = 1-P_i(FB)$.

The relay candidate with the minimum utility value *TuPi* wins the contention and is selected as the relay node. After sending an ETH frame, it helps the source node by retransmitting the packet *x* to the destination. Upon correctly decoding the packet, the destination node sends an ACK back to the source node.[6]

IV. TRIPLE BUSY TONE MULTIPLE ACESS

We explain the operation procedure of the proposed Cross layer Triple Busy Tone Multiple Access (CTBTA) protocol. In this method, node A wants to send data to node B, while node G has already been sending data to node F. In the figure, a solid line between any two nodes indicates that they can hear each other, and an arrow denotes a transmission. When node A has data to send, it first senses the three busy-tone signals, BTt, BTr, and BTh. If no busy-tone signal is detected, which means that none of the nodes in its transmission area (i.e., nodes B, C, D, E, and H) is in the packet reception state, node A turns on its BTt signal, sends an RTS packet to node B, sets up a timer $TS1$, and waits for a response from node B. The timer is given by

$$TS1 = TRTS + \tau + TCTS + \tau$$

where $TRTS$ and $TCTS$ are the transmission times of RTS and clear-to-send (CTS) packets, respectively, and τ is the propagation delay. If no CTS packet from node B is received by node A before the timer $TS1$ expires, node A will turn off its BTt signal and give up the transmission.[5] When node B receives the RTS packet, if neither BTr nor BTh signal is detected, it first turns on its BTr signal as an indication of a successful reservation, and then sends back the CTS packet including its estimated signal to noise ratio (SNR), and sets up a timer $TD1$ as

$$TD1 = TCTS + \tau + Td + \tau + TDATA + \tau$$

Where Td is the busy-tone detection delay which depends on the communication hardware and might not be negligible, $TDATA$ is the transmission time of a data packet that can be calculated based on the date transmission rate and packet length. The timer $TD1$ is used to account the time in which node B should receive the data packet from node A if no helper exists. If no data packet is received in $TD1$, node B turns off its BTr busy tone. Node A monitors the BTr signal and waits for the CTS packet from node B. Once the CTS packet is received, node A sets up a new timer $TS2 = Td + \tau$, and waits for response from potential helpers.[7] If there is no BTh signal detected before the timer $TS2$ expires, which means that no helper has the ability to improve the instantaneous throughput of transmission from node A to node B, node A turns off its BTt signal and starts to send the data packet to node B with the transmission parameters (e.g., modulation mode and coding rate) chosen according to the SNR information included in the CTS packet. Otherwise, node A keeps transmitting its BTt signal until it receives the ready-to-help (RTH) packet from an optimal helper.[8] Note that different from DBTMA, where an existing receiver (e.g., node F in Fig. 1) turns on its BTr busy tone during the data packet reception, in our scheme it is the potential receiver (e.g., node B) which just received an RTS packet that turns on its BTr busy tone to protect the reception of the RTH.

For an existing receiver (e.g., node F) during its packet reception, it will turn on the BTh busy tone (rather than the BTr busy tone) to protect its data packet reception.[10] If all the receivers (e.g., nodes F and B) use a BTr busy tone to protect their receptions, a helper cannot distinguish whether a BTr busy tone is sent by its own receiver or by any other existing receiver. Next, we discuss how to choose an optimal helper without interfering with other existing transmissions.[11] Assume that nodes C, D and E all have the ability to improve the instantaneous throughput of the transmission from node A to node B. The ability of a node to cooperate a transmission in CTBTMA is measured by a utility value. The larger the utility value, the better the ability. Any node that receives both RTS and CTS packets and does not sense a BTh signal calculates its utility value according to the Cross layer algorithm. In the example of Fig. 1, because of the BTh signal from the existing receive node F, node E will not contend to be a helper in order not to corrupt the reception of node F. On the other hand, without sensing a BTh busy tone, nodes C and D will contend to be a helper. They send out their busy tones in the BTh channel. The length (i.e., time duration) of the BTh busy-tone signal is a function of the utility value.[12] The larger the utility value, the longer the BTh busy-tone transmission. After exhausting its BTh busy tone signal, a potential helper (say node C) senses the BTh channel.[14] If the BTh channel is busy, which means that at least one other node is transmitting a longer BTh busy-tone signal (implying that a better helper exists), node C will give up. If the BTh channel is idle, which means that node C is the optimal helper, it will send an RTH packet including the optimized transmit parameters (transmission type, modulation and coding scheme) to node A and node B. At the same time, node C continues to send its BTh busy-tone signal to protect its packet reception during cooperation. Upon receiving the RTH packet, the destination (e.g., node B) switches its busy tone signal from the BTr channel to the BTh channel, and the source (e.g., node A) turns off its BTt busy tone and starts to send a data packet.[9] If a destination does not detect a BTh busy tone within $\tau + TS2$ after sending a CTS packet (which means that no helper exists), it switches its busy tone signal from the BTr to the BTh channel. After receiving (sending) the RTH packet, node B (node C) initiates a timer $TD2$ (TH) given by

$$TD2 = \begin{cases} T^{SD}{}_{DATA} + \tau & \text{if cooperative tx} \\ T^{SH}{}_{DATA} + \tau + T^{HD} DATA + \tau & \text{if two-hop tx} \end{cases}$$

$$TH = T^{SH}{}_{DATA} + \tau$$

where $T^{SD}{}_{DATA}$ is the transmission time of a data packet through the source-destination channel, $T^{SH}{}_{DATA}$ and $T^{HD}{}_{DATA}$ are the transmission times of a data packet through the source helper channel and helper-destination channel, respectively.[13] In cooperative transmission, a destination receives the data signals from both the source and the helper. In two-hop transmission, a destination receives the data signal only from the helper. Once the destination receives the data packet, it

V. NODE SELECTION ALGORITHM

Node selection algorithm is given as follows:

Step 1: In Tx cluster, every node N_{ti} transmit training sequence to Rx cluster with a broadcast in a pre-assigned slot i S in sequence $S_i \in (S_1, S_2 \ldots. S_{Nt})$.

Step 2: after receiving training sequence from Tx, every node j ,$1 \le j \le N_r$, in Rx cluster estimate the channel fading coefficients $\mathbf{H}_i = [h_j, h_{ji}\ h_{jNt},]$, $1 \le i \le N_t$.

Step 3: every node rj N in Rx cluster transmit the fading coefficients j H to the destination (or relay node) in a pre-assigned slot $S_i \in (S_1, S_2,.. S_{Nt})$.

Step 4: The destination node in Rx cluster collects all the channel fading [$\mathbf{H}_1, \mathbf{H}_2, \mathbf{H}_{j,} \ldots \mathbf{H}_{Nr}$], and then calculates all 2 ij h of the matrix $\mathbf{H} = [\mathbf{H}_1, \mathbf{H}_2, \mathbf{H}_j.. \mathbf{H}_{Nr}]^T$, after that, we could acquire

$$A_i = \sum_{j=1}^{Nr} |hji|^2 \ , \ i=1\ldots..N_t$$

Let B_i be the order of A_i , $B_1 \ge B_2 \ge \ldots.., \ge B_{Mt} \ge \ldots\ldots, \ge B_{Nt}$ (for example $B = \max(A1\ldots, A_{Nt})$). At last, We could gain the better transmitting nodes serial number 1…, M_t , where their corresponding value $A_i \in (B_1 \ldots. B_{Mt})$. Similarly, the better receiving nodes 1…., M_r could be got by destination.

Step 5: The destination node transmits the set Ω (where $\forall i \in \Omega$, $A_i \in (B_1 \ldots. B_{Mt})$. to Tx cluster by the feedback channel. This message includes only several bits. Compared with the kbits order of the data transmission, the energy consumption of the feedback is very small, so it can be ignored.

Step 6: The node in Tx cluster could know whether to transmit in cooperation method by the feedback message. Then the selected M_t nodes of Tx cluster begin to transmit data message in cooperation. If correlation time is over, it will go to Step 1. From these Steps, it can be know this new scheme has the same energy consumption in the local cluster compared with traditional algorithm (we ignore the consumption of circuit energy in feedback), but it could save a lot of energy in the stage of transmitting data in long haul distance. [15] Because we choose the transmitting nodes and receiving nodes according to acquiring the maximum SNR in Rx cluster.[16] So it could get more diversity gain than traditional algorithm. This scheme is very suitable to participate where a lot of nodes could be selected to cooperate.[17]

VI. CONCLUSON

In this paper, the various cooperative communication schemes such as pure-cooperative communication, Triple busy tone multiple access and Node selection algorithm are discussed. These schems are very helpful to find a route when network topology changed periodically. Cooperative node can update the information through relay nodes and forward the packets successfully to destination.

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