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Energy-Efficient Topology Control with Selective Diversity in Cooperative Wireless Ad Hoc Networks: An Overview

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ABSTARCT: The Cooperative Communication is a technology that allows multiple nodes to simultaneously transmit thesame data. It can save power and extend transmission coverage. However, prior research work on topology controlconsiders CC only in the aspect of energy saving, not that of coverage extension. We identify the challenges in thedevelopment of a centralized topology control scheme, named Cooperative Bridges, which reduces transmission power ofnodes as well as increases network connectivity. Prior research on topology control with CC only focuses on maintainingthe network connectivity, minimizing the transmission power of each node, whereas ignores the energy efficiency of paths inconstructed topologies. This may cause inefficient routes and hurt the overall network performance in cooperative ad hocnetworks. we propose a distributed energy-efficient selective diversity(EESD) topology control to improve energy efficiency in thenetwork, which jointly considers network capacity and energyconsumption in terms of bits per Joule. EESD forms transmissioncoalitions via cooperative manner (i.e, diversity) selections, bytaking into account the cost of channel information exchange.We then formulate EESD as a coalition game and propose anadaptive coalition formation algorithm for EESD with proved convergence property and stable coalition structures. Simulationresults show the performance improvement of EESD in energyefficiency compared to the existing topology control system.

KETWORS: Cooperative communication, topology control, power efficient, greedy algorithm, Optimum relay.

I. INTRODUTION

Increasing demand for high-speed wireless networks has motivated the development of wireless ad-hoc networks. In order to fully exploit the technological development in radio hardware and integrated circuits, which allow for implementation of more complicated communication schemes, the fundamental performance limits of wireless networksshould be reevaluated. In this context, the distinct characteristics of wireless networks compared to their wired counterpartlead to more sophisticated design of protocols and algorithms. Some of the most important inherent properties of thePhysical Layer (PHY) that make the design more complicated include the attenuation of radio signals over long rangecommunications called path loss, and the fading effect caused by multipath propagation. In order to mitigate these effects,the user has to increase its transmission power or use more sophisticated reception algorithms. Another important limitationof wireless performance caused mainly as a result of communication over a limited bandwidth is the interference from otherusers, communicating over the same frequency spectrum.Wireless ad hoc networks are multi-hop structures, which consist of communications among wireless nodes withoutinfrastructure. Therefore, they usually have unplanned network topologies. Wireless ad hoc networks have various civilianand military applications which have drawn considerable attentions in recent years. One of the major concerns in designingwireless ad hoc networks is to reduce the energy consumption as the wireless nodes are often powered by batteries only.

Wireless nodes need to save their power as well as sustain links with other nodes, since they are battery powered. Topologycontrol deals with determining the transmission power of each node so as to maintain network connectivity and consume theminimum transmission power. Using topology control, each node is able to maintain its connection with multiple nodes byone hop or multi-hop, even though it does not use its maximum transmission power.

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Consequently, topology control helpspower saving and decreases interferences between wireless links by reducing the number of links. Topology control [1-4] isone of the key energy saving techniques which have been widely studied and applied in wireless ad hoc networks. Topologycontrol lets each wireless node to select certain subset of neighbors or adjust its transmission power in order to conserveenergy meanwhile maintain network connectivity.Topology control have been widely studied and applied in wireless ad hoc networks as one of the key energy savingtechniques. In order to save energy and extend lifetime of networks topology control lets each wireless node to select certainsubset of neighbors or adjust its transmission power meanwhile maintain network connectivity. Recently, a new class ofcommunication techniques, cooperative communication (CC) [37], [38], has been introduced to allow single antenna devicesto take the advantage of the multiple-input-multiple-output (MIMO) systems. This cooperative communication explores thebroadcast nature of the wireless medium and allows nodes that have received the transmitted signal to cooperatively helprelaying data for other nodes. Recent study has shown significant performance gain of cooperative communication in variouswireless network applications: energy efficient routing [39]–[41] and connectivity improvement [42].

In this paper, we study the energy efficient topology control problem with CC model by taking the energyefficiency of routes into consideration. Taking advantage of physical layer design that allows combining partial signalscontaining the same information to obtain the complete data, we formally define cooperative energy spanner in which theleast energy path between any two nodes is guaranteed to be energy efficient compared with the optimal one in the originalcooperative communication graph. We then introduce the energy-efficient topology control problem with CC (ETCC), whichaims to obtain a cooperative energy spanner with minimum total energy consumption,The cooperative communication techniques can also be used in topology control. In [35], Cardei et al. first studiedthe topology control problem under cooperative model (denote by TCC) which aims to obtain a strongly-connected topologywith minimum total energy consumption. They proposed two algorithms that start from a connected topology assumed to bethe output of a traditional (without using CC) topology control algorithm and reduce the energy consumption using CC model

II. LITERERTURE REVIEW

In general, routing in WSNs can be divided into three types, viz. flat structure based routing, hierarchical structure based routing and location-based routing [3][4]. In flat structure based routing [5][6], all nodes are typically assigned equal roles or responsibilities. In typical hierarchical structured based routing [7][8][9], however, nodes play different roles in the network depending on their position in the hierarchy In location-based routing [10] [11], sensor nodes' positions are exploited to route data in the network. In the recent past, many routing protocols have been proposed for sensor networks. The descriptions of some of these protocols are as given below. Heinzelman, Kulik, and Balakrishnan have proposed a protocol, called Sensor Protocols for Information via Negotiation (SPIN) [12], that provides data-centric routing approach where the data should be named using high level descriptors or metadata. The SPIN is a family of many protocols. The two main protocols are called SPIN-1 and SPIN-2. The SPIN-1 protocol is a 3-stage protocol, but does not consider any energy aware technique. However, in SPIN 2, when energy in the nodes is abundant, it communicates using the 3-stage protocol of SPIN-1 . However, when the energy in a node starts approaching a low energy threshold it reduces its participation in the protocol, that means, it will participates only when it believes that it can complete all the other stages of the protocol without going below the threshold energy level. Ye, Chen, Lu, and Zhang have proposed an algorithm, called Minimum Cost Forwarding Algorithm (MCFA) [13] that sets up a back off based cost field to find the optimal cost path from all the nodes to the sink. Once the field is formed, the message, carrying dynamic cost information, goes along with minimum cost path in the cost field. This protocol consists of two phases. First phase is a setup phase for setting up the cost value in all nodes. In the second phase, the source broadcasts the data to its neighbors nodes. To minimize the number of broadcast messages, the MCFA was modified to run a back off algorithm at the setup phase. The back off algorithm dictates that a node will not send the updated message until back off time units have elapsed from the time at which the message is updated. Problems with the algorithm are high consumption of bandwidth and it may cause duplicate copies of sensor messages to arrive at the sink. In Power Aware Chain (PAC) [14] routing protocol proposed by Pham, Kim, Doh, and Yoo, all nodes organize themselves into the energy efficient chain with the help of MCFA protocol and depth first search. One node, elected as leader node, transmits data back to sink on behalf of all other nodes. Leader node election is based on the power available and the power needed for transmission from the node to sink. Each node aggregates received data from the previous node in the chain with its own collected data to produce an aggregated data packet.

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In the recent past, Hong and Yang have proposed an energy balanced multipath routing protocol for sensor network [8] which is based on rumor routing technique. In this protocol, authors consider a probabilistic approach to find multipath from source to sink by considering the residual energy and hop count from source to sink. Chakchouk, Hamdaoui, and Frikhax also have proposed a protocol [9] that uses remaining energy and the hop count from sensor node to the sink in order to make hop-by-hop energy-aware routing. There are some energy aware routing protocol like [7][14] which use hierarchical or cluster based approach by considering the residual energy or remaining energy to distribute the traffic over the whole network and also prolong the network lifetime. S. Lindsey *et al.* proposed an algorithm related to LEACH, called PEGASIS [4]. According to these authors for a node, within a range of some distance, the energy utilized for sending or receiving circuits is greater than that consumed for amplifying circuits. To reduce this energy consumption, PEGASIS uses the GREED algorithm to make all the sensor nodes in the system in a chain. According to the simulation results, the performance of PEGASIS is better than LEACH, particularly, when the distance between sink node and sensor network is too large. In [5], to deal with the heterogeneous energy condition, node with the higher energy should have the larger probability to become the cluster head. Each node must have information of energy level of all nodes in the network to verify the probability of its becoming a cluster head. So, each node will not be able to make a decision to become a cluster head if only its local information is known. In such conditions, the scalability of this protocol will be influenced. Sh. Lee *et al.* proposed a new clustering algorithm CODA [6] in order to relieve the imbalance of energy run down caused by different distances from the sink.

CODA divides the whole network into a groups based on node's distance to the base station and the routing policies. All groups have its own number of clusters and member nodes. CODA Algorithm differentiates the number of clusters in terms of the distance to the base station. As longer as distance between the member node and the base station, the more number clusters are formed in case of single hop with clustering. It gives better performance in terms of the network lifetime and the dissipated energy than those protocols that apply the same probability to the whole network. However, the functioning of CODA depends on global information of node position, and thus it is not scalable. All the routing protocols discussed above are based on energy-aware technique. But, to minimize energy consumption and prolong the lifetime of the network, the routing protocols have to support sleep scheduling schemes so that most of the nodes are put to sleep, and the remaining nodes are active. There are very less routing protocols that support sleep scheduling and some of them are described below. Hou and Tipper have proposed flat structure based employs probabilistic based sleep modes. At the beginning of a gossip period, each node chooses either to sleep with probability p or to stay awake with probability $1- p$ for the period, so that all the sleep nodes will not be able to transmit or receive any packet during the period. When an active node receives any packet, it must retransmit the same. All sleeping nodes wake up at the end of each period. All the nodes repeat the above process for every period.

III. SYSTEM ARCHITECTURE

An arbitrary wireless network can be modeled as a directedgraph G(N, E), where the set N includes all the n nodes inthe network and E is the the wireless links set. Let Ti be atransmission from the source node Si to the destination nodeDi. The transmission Ti can be achieved through differenttransmission patterns with or without the help of relay nodes,leading to different diversity. However, a transmission canonly be carried out in any one transmission pattern, resultingin selective diversity. To interpret the transmission clearly, adefinition for transmission pattern is introduced as follows:

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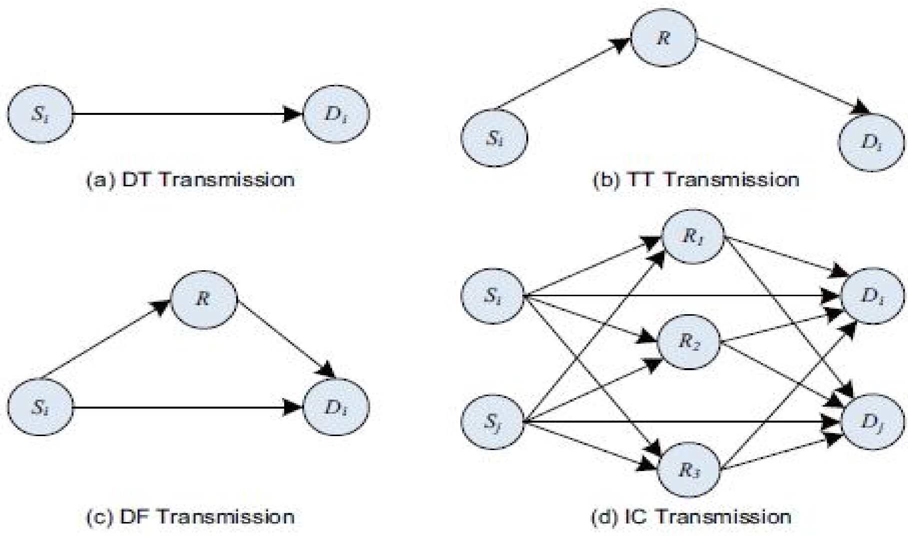

Fig. 1 Transmission Pattern of Proposed System

Transmission pattern: For a transmission T_i,transmission pattern is $g(T_i) = (R, h(R))$ where R is the relay nodes set and h(R) is the way these relay nodes work.In this paper, we will study four transmission patterns withdifferent cooperation diversities as shown in Fig.1.

(1) Direct transmission (DT): DT transmission is a singlehoptransmission. S_i transmits directly to D_i using one slotand no relay node is involved. Therefore, $R = \emptyset$, h(R) = DT.

(2) Two-hop transmission (TT): TT transmission is one typeof multi-hop forwarding and used here as a representative. InTT transmission, S_i transmits a packet to intermediate nodeR as a relay in the first slot, which decodes the packet andforwards it to D_i in the second slot. D_i decodes the signalsonly from the relay. Therefore, R = {R}, h(R) = TT.

(3) Decode-and-forward relay transmission (DF): In DFtransmission, S_i transmits signals to intermediate node R as arelay in the first slot, which decodes the received signals andforwards them to D_i in the second slot. The combined signalsreceived from the source S_i and from the relay R are decoded at D_i jointly. Therefore, R = {R}, h(R) = DF.

(4) IC cooperative transmission (IC-based): There is a cooperativetransmission $T_j$and three assisting relays R_1,R_2,R_3.In the transmission, S_i and $S_j$broadcast their packets tothe three relays concurrently in the fist slot. In the secondslot, each relay scales the received signals and forwardsthem to the destination concurrently [2]. Therefore, we haveR = $\{R_1,R_2,R_3\}$, h(R) = IC.

The focus of this paper is to form an energy-efficientnetwork topology via the selection of transmission patterns.The metric of energy efficiency is discussed in the following

Energy efficiency) : Energy efficiency refersto the achievable information transmission per Joule energyconsumption with bits per Joule as the unit, i.e.,

$$E_{g(\mathcal{T}_i)} = \frac{C_{g(\mathcal{T}_i)}}{P_{g(\mathcal{T}_i)}},$$

Where $P_{g(T_i)}$ and $C_{g(T_i)}$ are the total power consumption and the achievable throughput in a transmission T_i with transmission pattern $g(T_i)$.

Therefore, for all the transmissions T in a network, the overall network energy efficiency is

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$$f(g(\mathcal{T})) = \sum_{\mathcal{T}_i \in \mathcal{T}} E_{g(\mathcal{T}_i)} = \sum_{\mathcal{T}_i \in \mathcal{T}} \frac{C_{g(\mathcal{T}_i)}}{P_{g(\mathcal{T}_i)}}.$$

Obviously, the topology with larger f(g(T)) has better energy efficiency performance. To achieve the optimal total networkenergy efficiency, transmission patterns should be selected dynamically according to the network conditions.

IV. ALGORITHM

Algorithm 1 Coalition Establishment Algorithm on behalf of EESD

Initialization:

Adjust the network divider, i.e., each node of N andeach broadcast pair of T forms a association, S ={S1, E E E ,Sn, Sn+1, E E E , Sn+t}, wherever Si = {Ni}, 1 . i .n and Sj = {Tj}, n + 1 . j .n + t.

Adaptive Coalition Formation:

Coalition establishment using merge-and-split occurs.
Repeat:
a) The federation Si tries to combine with Sjbestowing to the
Merge Rule.
b) Federationschoose to split established on the Pareto instructionaccording to Split Rule.
Until: Merge-and-split restatementdismisses
Output Partition and Transmission:
A steady new partition S is produced and transmissions twitchwith the optimal conduction pattern.

V. CONCLUSION

In this paper we overview the proposed system Distributed Energy Efficient Selective Diversity (EESD) base on the topology control system for co-operative wireless ad-hoc networks. We also explain the distributed user cooperation in selective energy efficient transmission patterns, which leads to selective diversity. EESD is formulated into a coalition game and an adaptive coalition formation algorithm is developed to form energy-efficient transmission coalitions considering the cost of channel information exchange. We have also got idea convergence of the algorithm and stability of the convergence.

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