New Cross Layer Topology Control Scheme for IEEE 802.16e-based Multi-radio Multi-channel Hybrid Ad Hoc Networks

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Abstract: A special scenario of the topology in the multi-radio multi-channel hybrid Ad Hoc networks is studied and a new cross layer topology control scheme based on IEEE 802.16e is proposed in this paper. The proposed scheme integrated the attributes both of the new performance evaluation machine check time metric and the topology space in the special scenario. Due to the minimum link occupation, the traffic requirements, the maximal amount of the permitted hops, the aggregated throughput and the scheme overhead are all optimized with the different metrics.

1. Introduction

The hybrid Ad Hoc networks[1] give a novel infrastructure which combines cellular network with Ad Hoc mechanism. We believe that the topology space analysis in the special scenario should be beneficial for the proposal of a novel scheme. In this paper, based on the special scenario of the network topology we explore the relationship between attributes of the topology space and the topology scenario. To this end, we propose a new performance evaluation metric and the novel scheme to effectively utilize location marking information and then address the performance issues.

Each node makes decision independently in the hybrid networks, it may cause inconsistence and confusion when two nearby nodes adjust their topology simultaneously[2]. Thus it is required that both the channel adjustment and power adjustment should guarantee the exclusiveness of the cross layer adjustment in node's interference area. Under this premise, each node may locally make adjustment decisions without considering the disturbance of neighboring nodes. The multi-radio multi-channel network we considered is denoted by $G(V,E)$ where V is the set of nodes and E is the set of links. Let $G_T(V,E')$ represent the graph induced by the topology control scheme and $G_A(V,E'')$ represent the graph induced by the channel assignment scheme where $G_A \subseteq G_T \in G$ .Consequently with this arrangement a mobile node can be formed, which can operate in both infrastructure and Ad-hoc mode. Communication between mobile nodes in different cells is accomplished through their respective domain in a similar fashion as conventional cellular networks.

The rest of this paper is organized as follows. In Section 2, we give the evaluation models and make the dimensionality analysis of the topology. In Section 3, we propose the performance evaluation metric and the new scheme. In Section 4, we evaluate the performance of the proposed scheme and analyze the improvement of the guarantee via simulation. Finally we give the conclusion in Section 5.

2. Dimensionality Analysis of Topology and Evaluation Model

The evaluation model is the multiple cell environment with seven cells as shown in Fig.1, in which the Mobile Hosts (MHs)[2] are in point wise uniformity. Let $E = C_1 \bigcup C_2$ and C_1 is the compact subset of E. As for the open covering U, it is composed of the neighborhood basis of E and the finite subset U' of U can cover C_1. Then $E / \bigcup U'$ is the finite set and U has finite sub-covering. $\{\{e\} : e \in C_2\}$ is the disjoint uncountable open set family of E, so that E is not a metrical compact space. Let $K_1 \neq \phi$, then if p has a countable basis in the compact metric space and $\{F_n\} \in G_1$ is the finite covering of K_1. $F_n = \{V(e_n, i) : i \le K_n\}$, where $V(e_n, i)$ is an open arc at the center of C_1. For each neighborhood of K in E, if $e \in K_n$ then there should be an arc $V(e)$ of C_1, which has its center at e and $V(e) \bigcup p(V(e)/\{e\}) \subset U$ .Due to the compactification

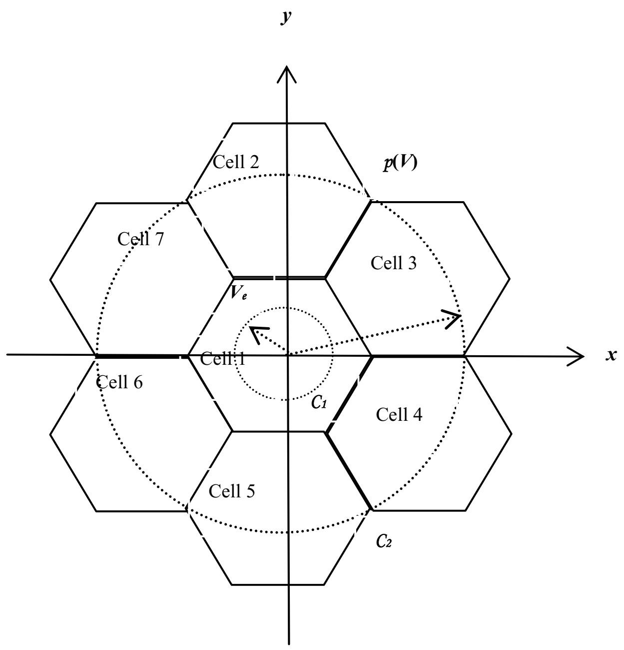

Fig.1. Dual ring topology scenario with multiple cells

of *K*, we have $K_n \subseteq U_n \subseteq U$ and each compact sub-set has a countable neighborhood basis in *E*. Therefore, the Dual Ring topology belongs to the Alexandroff Dual Ring space[3]. The attributes of Alexandroff Dual Ring space are potentially worthy for the topology control scheme. And what is more, the attributes of Alexandroff Dual Ring Space are potentially worthy for the Location Information (LI) application and power control game. However, a distinct difference in this case is that MHs themselves can also function as active mobile nodes in IEEE 802.16e. These nodes under group-oriented operation are capable of initiating communications not only with their mobile nodes, but also with others. So, the attributes of Gillman-Jerison Space are potentially worthy for the novel scheme proposal.

3. Performance Evaluation Metric and Cross Layer Topology Control Scheme

The physical layer sub-problem addresses the transmission interference among nearby nodes and provides to the upper layers a convex set of capacity graphs supported by a finite set or basis of elementary capacity graphs. Generally speaking, both the channel diversity and spatial reusability affect the network performance in multi-radio multi-channel Ad Hoc network.

In our relative works, we have studied the Time Metric (TM) and the Machine Time Metric (MTM). In this paper, we propose a new performance evaluation Machine Check Time Metric (MCTM), defined as:

$$\mathrm{MCTM}_i = \sum_c \sum_l r_l^c RT_l^c F^c Q_l / CF^c \qquad (1)$$

where *c* represent the available channels and l denotes co-channel links that lie in the interference range of a specific node *i*, RT_l^c denotes the round trip factor of the corresponding channel, Q_l specifies the quality of the link, CF^c denotes the channel reuse factor on channel *c*. MCTM represents the aggregated equivalent channel air time for potential candidates and acts as an indicator for the network performance. When the end-to-end traffic can be split in the cross topology, the number of the routes between source and destination should be more than one. That is to say, the flow going through the route is no longer an integer and the traffic demands can be split[4].

When the end-to-end traffic can be split in the topology, the number of the routes between source and destination should be more than one. That is to say, the flow going through the route is no longer an integer and the traffic demands can be split[5]. The relative constraints are shown below.

Bandwidth constraints:

$$\sum_j \sum_{(t,d)} y_{ij}^{td} + \sum_j \sum_{(t,d)} y_{ji}^{td} \le B \quad \forall i,j,t,d \in N \qquad (2)$$

in which y_{ij}^{td} is the amount of traffic of node pair (*t*, *d*) that goes through link (*i*, *j*), *B* is the maximal bandwidth and $y_{ij}^{td} \ge 0, \forall i,j,t,d \in N$.

Route constraints:

$$\sum_j y_{ij}^{td} - \sum_j y_{ji}^{td} = \eta_{td}, \quad i=t$$

$$\sum_j y_{ij}^{td} - \sum_j y_{ji}^{td} = -\eta_{td}, \quad i=d$$

$$\sum_j y_{ij}^{td} - \sum_j y_{ji}^{td} = 0, \quad otherwise \qquad (3)$$

in which η_{td} is the traffic requirement and $y_{ij}^{td} b_{ij} \ge y_{ij}^{td}$.

Interference constraints:

$$I(e) = \sum Load(i_l) \qquad (4)$$

in which *I*(*e*) experienced by the link $e \in E$ is the sum of the traffic load on all the interfering links and i_l denotes the interfering link.

In our scheme, the topology and power consumption of each node can be optimized due to the minimum link occupation. The power update is the best response of link player given the tax rate and assessment of others' action.

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Init( )
{
 for each available channel c ∈ {c1,c2,...,cL}
if t=0
jprio=Prand(i)W(i);
else if
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$j_{prio}= Prand(i)W(i)\ CF^c$;
end if
analyze the contention of links on channel *c* in two hop range;
if *i* is bound to nodes of neighboring cluster then
Assign *i*, the channel assignment from its neighbor assignment;
else
Calculate new assignment for (v,i);
end if
calculate $MCTM_i$ value on channel *c* and corresponding priority for each group;
Clusterhead(*i*)
{
for $j \in Ni$
if $Prand(Ni) < W(j)$ and priority of t is not Φ
Recover *Ni*;
end if
}
if feasible
then select adjustment candidate with minimal MCTM value and begin negotiation;
end if
}

The topology construction is performed during the network initialization phase when no user traffic is present in the multi-radio multi-channel network. It is not good enough only considering channel assignment. To fully reduce the co-channel interference and consequently achieve higher gains of network performance, the topology control and routing should be jointly considered to exploit not only channel diversity but also spatial reusability. Firstly, we sort all the node pairs in ascending order according to their minimum distance. Secondly, MCTM runs on every node in the network to check whether the flow can be all routed or not. The operation should be terminated when the transmission power reaches to maximum. In this scheme, the topology and power consumption of each node can be optimized due to the minimum link occupation. The power update is the best response of link player given the tax rate and assessment of others' action. As for the tax rates converge, it can be induced to a stable Nash equilibrium. Such power allocation equilibrium strikes a balance between minimizing interference and maximizing rate.

4. Simulations

The terrain model we used is a $100km \times 100km$ square area with seven cells in it, on which 50000 MHs are pseudo-randomly moving along the cluster cells. All the MHs are presented by $\{u_i\}$ $i \in [1, 50000]$, and all the links between MHs are bi-directional. Each cell has a base station with omni-directional antenna at the center point and its radius is $15km$. Each base station has 1024 available data channels. We use the modified DSR protocol with location information as the routing protocol for the Ad Hoc mode. Assume the power consumption is based on the distance from the transmitting MHs to the base stations. As for handoff mechanism, hard handoff was used in the evaluation model and connectivity is considered under Poisson Boolean Model in this kind of sparse network. We use 4096 TCP flows in the special scenario and the simulation time for each point is $3600s$. Employing TM, MTM and the proposed scheme, the simulations are performed. The traffic requirement and the maximal amount of the permitted hops are examined in different load and transmitting power of the nodes with or without MTM, shown separately in Fig.2, Fig.3.

Fig.2 shows the different values of the traffic requirement along with the load of the nodes with or without MTM. We can see that the traffic requirement depend deeply on the load when use no MTM but released by MTM from it. The maximal optimization is 8.31% when the load reached to 200Mb/s. What is more, the addressing ratio of success in the condition of the unchanged parameters and external information can also be increased. The maximal amounts of the permitted hops in different loads are shown in Fig.3. The value is fixed when the load is 0, that is to say, the default value of the hops is 1 when the nodes have no load. The network can tolerate more hops to support reliable transportation with the help of MTM, it can make the network more stable and can support more hops. The maximal optimization is about 10.19% and the merits of the proposed scheme are obvious.

We also evaluate the impact of varying the number of flows in the network. Fig. 4 compares the throughput of joint adjustment with no adjustment. Ten flows are setup between randomly chosen node pairs. The traffic load on each flow is 4.5Mbps. It is apparent that joint adjustment offers significantly better performance than network without adjustment, averagely 2 times the throughput of network without adjustment.Fig. 5 plots the overhead of joint adjustment. The overhead includes the cost of sending link probe packet for measuring packet loss ratio, neighbor information exchange and the adjustment negotiation. The aggregated overhead increases monotonically with the number of nodes and flows. Nevertheless, the overhead per node remains small, and consumes only a small fraction of the available channel capacity.

5. Conclusions

Based on the analysis of the topology space and cross layer constraints, we induced the special scenario of the topology in the multi-radio multi-channel hybrid Ad Hoc networks. With the help of the topology analysis, we proposed a new performance evaluation time metric and a

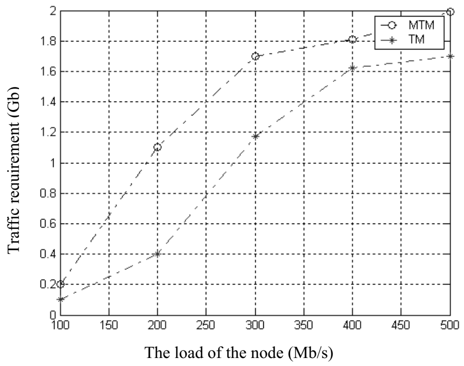

Fig.2. Traffic requirements for different loads

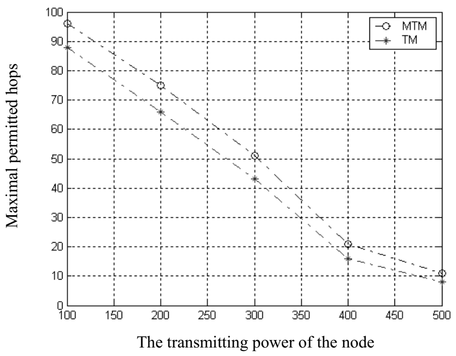

Fig.3. Maximal amount of the permitted hops in different loads

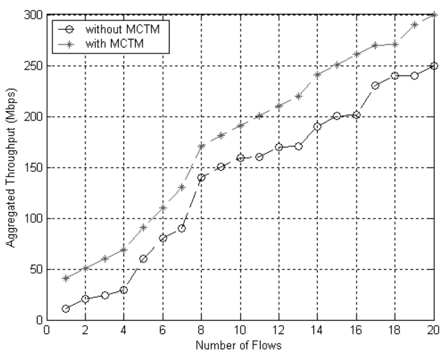

Fig.4. Aggregated throughput with varying number of flows

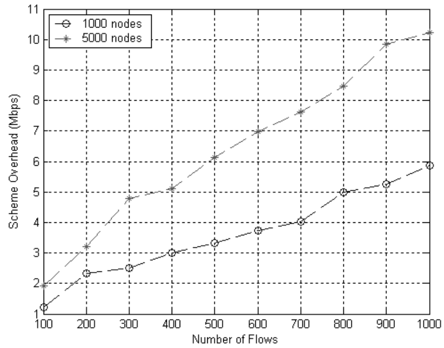

Fig.5. Scheme overhead with varying number of flows and nodes

novel cross layer topology control scheme based on IEEE 802.16e in this paper. The proposed scheme integrated the attributes both of the new metric and the topology space in the special scenario. Both the topology and the power consumption of each node are optimized due to the minimum link occupation with the help of the scheme. Simulation results show that the new scheme can give power control guarantee to the multi-radio multi-channel networks in the variable node loads and transmission powers.

Acknowledgments

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