# Cooperation Incentives between Wireless Mesh Network Operators

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## 1 Motivation and Problem

In wireless mesh networks, low transmission rate links create bottlenecks that degrade the end-to-end throughput. To make matters worse, low rate links degrade the performance of neighboring links that operate on the same channel, due to the long duration of low rate transmissions and the per-packet fairness of the 802.11 MAC protocol [1].

One approach for mitigating the performance degradation due to low rate links is to consider routing protocols with metrics such as ETT [2], WCETT [2] and CATT [3], which take the transmission rate into account. In wireless LANs, another approach is to use relay nodes in order improve performance by having multiple high rate transmissions instead of a single low rate transmission [4][5]. The above works either focus on a single network or assume full cooperation between the nodes. Our work, on the other hand, considers the case of wireless mesh networks which belong to different operators, which act in their own self-interest. For such a scenario, we investigate the incentives for cooperation due solely to performance improvements that cooperation can yield for all mesh networks.

## 2 Performance Incentives for Cooperation

Consider two mesh networks, $A$ and $B$. An overlapping part of these networks consists of a sequence of four nodes, $A_1$, $B_2$, $A_2$ and $B_1$. Network $A$ has traffic originating from $A_1$ and destined to $A_2$, while network $B$ has traffic originating from $B_1$ and destined to $B_2$. Without cooperation, there are two flows from $A_1$ to $A_2$ and from $B_1$ to $B_2$ respectively, Fig. 1(a). When the two mesh networks cooperate, Fig. 1(b), nodes $B_2$ and $A_2$ forward the traffic of the mesh networks $A$ and $B$, respectively. As a result, the traffic from $A_1$ to $A_2$ flows through $B_1$, and the traffic from $B_1$ to $B_2$ flows through $A_1$.

As a first step, we assume that all mesh nodes operates at the same channel. This scenario arises in dense networks, when the orthogonal channels are limited, e.g. wireless networks operating at the 2.4GHz band. The model we present,


(a) No Cooperation. (b) Cooperation.

**Fig. 1.** Overlapping Wireless Mesh Networks.

however, can be extended to the case of multiple channels and mesh nodes with multiple radio interfaces.

Assuming that the MAC layer protocol provides long-term fairness in medium access, as can be assumed for 802.11 DCF, the long-term end-to-end throughput of each mesh network is

$$X^a = \frac{1}{\frac{1}{R_{A_1A_2}} + \frac{1}{R_{B_1B_2}}} \quad \text{and} \quad X^b = \frac{1}{\frac{1}{R_{A_1B_2}} + \frac{2}{R_{B_2A_2}} + \frac{1}{R_{B_1A_2}}}, \qquad (1)$$

where $X^a$ and $X^b$ refer to the no cooperation and the cooperation case respectively and $R_{ij}$ is the rate of the links between the nodes $i$ and $j$. When the mesh networks cooperate, the same amount of data needs two hops to reach the destination. The ratio of $X^b$ over $X^a$ indicates when cooperation is beneficial for both mesh networks, and gives the corresponding gain. The above expressions can be extended to account for the protocol overheads.

As an example, consider that the wireless links use the 802.11b protocol. Assuming the scenario where the transmission rate of the links $A_1A_2$ and $B_1B_2$ is 1Mbps and the transmission rate of the links $A_1B_2$, $B_2A_2$ and $A_2B_1$ is 11Mbps, the model estimates that the cooperation yields 5.5 times increased end-to-end throughput for each mesh network.

## References

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