Improving uplink QoS of Wifi hotspots

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Abstract. Hotspots providers (using IEEE 802.11 Wireless LAN, also known as WiFi) are looking into ways to increase revenue from their service and improve customer satisfaction/experience. We propose a practical two-hop relaying scheme, managed by the Access Point (AP) to increase aggregate data throughput. We argue that controlled and incentives based collaboration among nodes and AP can improve overall QoS and hence the driving force for making relaying commercially viable.

1 Introduction

Relaying is where nodes communicate with their immediate neighbours to relay information for another node (to an AP in our scenario), with power control to minimize interference and/or maximize throughput. We propose a simple and practical two hop relay scheme where the AP centrally manages all nodes.

Consider a hotspot scenario: Node x situated at the edge of the hot-spot's ring of influence may be connected to the hotspot at a lower power transmission (due to its limited battery life left in his portable device) or lower transmission rate due to high interference. Node r who sits between node x and the hotspot could share power by acting as a relay and improve overall QoS. In doing so, a relay node can help to increase the throughput of the link since it may adapt to a higher data rate due to lower interference (e.g. nearer to AP). In highly concentrated (or busy) areas, an AP can preclude low data rate associations with distant nodes in an attempt to minimize delays (i.e. improve aggregate throughput of the busy network). However, using relays, benefits (i.e. aggregate throughput is proportional to revenue) are gained for both the hotspot provider and distant nodes. Related work such as [1] and [2] offer complex and impractical solutions for relaying in Wifi hotspots. They also do not consider the economic aspect of relaying (e.g. providing incentives) in their architectures, which we believe is essential to make relaying commercially successful. Ideally we want a scheme that benefits both the network operator, user and complies with standards.

In this paper, we introduce and briefly discuss our new research work on a simple handshaking protocol for selecting the best relay, incentive mechanisms and QoS issues for Wifi hotspots.

2 Handshaking protocol for hot-spots

Our initial design assumes that an AP always transmits at maximum power. Nodes within range can either reply to the AP directly using maximum power or through relaying via intermediate nodes using reduced power. Our approach requires the AP to build a virtual table of nodes corresponding to their signal strength that can be used to determine the appropriate relay node. One of the difficulties here is the location awareness of the nodes.

Let's say that it takes 100mW (an equivalent of 20dB) to transmit for a distance of 100 metres from AP to node x. Cisco has stated some theoretical calculations on estimating outdoor ranges and indoor ranges of wireless links [3]. In an outdoor wireless link scenario, the coverage distance doubles for every increase of 6dB (9dB for indoors). Similarly, the coverage in RF transmit power is reduced to half for every decrease of 6dB. To transmit from node x to AP takes 100mW. If node r is employed to do relaying, node x can therefore reduce its coverage distance (or range) by half. For outdoor wireless link condition, node x would take 25mW (14dB) to transmit to node r and with node r taking another 25mW to transmit to AP. In total, it takes 50mW (for indoors its 25mW).

Therefore, we can achieve a savings of 50% - 75% in terms of transmit power usage when using relaying excluding overheads such as relay reception power, relay protocol etc. Theoretically, in the best case, when high transmission rates are selected, using 802.11g, we can achieve 27Mbps throughput (x→r→AP), which is considerably better than 2Mbps (x→AP) at low transmission rate.

To identity the best relay, lets assume that node x is associated to the AP using a low transmission modulation rate (at 1Mbps). There are two possible ways to save power using a relay node. One is to use reduced power to transmit to a relay and the other to use the same power, but a high rate (e.g. 54Mbps) via the relay. In the latter case, you save power by reducing transmission time. Most importantly, an appropriate relay needs to be identified. We propose the following technique:

- Node x sends a relay request message at full power and low rate. All nodes, including AP will be aware of this request.
- Node x re-sends a relay request message at a reduced power (e.g. 50%) and high rate. AP may not be able to receive/decode this message successfully. However, nodes that receive this second message and if they are close to AP, would reply with a accept request message at full power. This is to ensure that AP and nearby nodes knows the relay.
- AP will choose the appropriate relay (assuming there is more than one) based on the power tables and policy (such as relay reliability and fair incentive distribution etc).
- Upon confirmation, Node x sends data at reduced power and/or at high rate. Relay node forwards data to AP.
- AP sends ACKs to Node x directly. Note that in this multi-hop scheme, all nodes are always within range of AP's maximum power.

The distance a signal can be transmitted depends on a various number of factors such as antenna gains, transmitter power and receiver sensitivity etc. Received signal strength is a measurement that is the difference between transmission signal strength minus path loss. In our scheme, the AP chooses a relay by checking from its table to select the node that is capable of being a relay based on it being able to fulfill a minimum received signal strength and it uses less transmit power than the other relay nodes. Only nodes that are within range of high data rate can be selected as relays.

To provide incentives each node has to be registered with a hotspot provider. This simplifies the management of security and incentives for relays. Nodes that are willing to share power must register with AP, and successfully close the session in order to gain benefits from AP. If a relay node disappears, timeout occurs, and this is followed by a new relay node being appointed by the AP. One way to provide incentives would be to credit a percentage of relayed message data to the relay account, when a successful transaction occurs. Any node sharing less than a pre-negotiated amount of time will not get any incentives. This also precludes malicious relay nodes. However, an unintentional disruption (e.g. movement, system crash, severe interference) to relaying may also result in this penalty. A relay rating policy may be used by the AP to rate relays based on their past performance.

4 QoS issues & summary

The described relay scheme should be QoS aware for optimal performance. For instance, in a real-time application, how do we minimize latency and jitter for node x when a relay node is used to forward uplink traffic? If the relay node prioritises different flows (locally), how should the AP police this to ensure fairness? One simple approach is to ensure that a relay node behave like two nodes, when relaying is enabled. That is, the contention window is halved, giving a much higher opportunity to access the AP for node x and relay node's own data. Alternatively the relay node could map individual flows according to the service differentiation (i.e. EDCA) as specified in the upcoming IEEE 802.11e. Or perhaps, the scheduling and admission control should be done at the AP to ensure minimal delays for distant nodes that require certain QoS guarantees. This makes it less complex for nodes, but likely incurs inefficient use of the wireless spectrum (e.g. retransmission of dropped/delayed packets of other nodes).

In addition, we have not considered the effect of mobility. Our approach assumes that nodes (including relays) intending to participate in this hybrid mode needs to be in a fixed location for at least the duration of the session.

References

1. Hao Zhu, and Guohong Cao, On Improving the Performance of IEEE 802.11 with Relay-Enabled PCF, Kluwer Academic Publishers, Mobile Networks and Applications, 9, 423-434, 2004.
2. Seungjoon Lee, Suman Banerjee and Booby Bhattacharjee, The Case for a Multi-hop Wireless Local Area Network, Infocom 2004.
3. Cisco RF Power Values. Document ID: 23231, http://www.cisco.com/warp/public/102/wlan/powervalues-23231.html, 2004