Towards Distributed Link-Layer Measurement of Wide-Area Wireless Networks

[Extended Abstract]

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1. INTRODUCTION

Current techniques for link-layer wireless measurement are limited in their ability to accurately capture the nature of a wide-area IEEE 802.11 wireless network. This extended abstract describes current research into development and deployment of a distributed link-layer measurement system for wireless wide-area networks. It is argued that by implementing measurement within the network, rather than externally as is traditional in wireless measurement, a much more accurate picture of the network behaviour can be obtained.

There is little research into how a wide-area wireless network interacts with itself. In cases where measurement has been attempted, it has generally been achieved by deploying passive measurement stations which are *external* to the network being measured, such as described in [3]. This technique however fails to accurately capture the channel conditions at the intended receivers of frames. For example, a frame captured by a passive external capture point may not have been received correctly by the intended receiver due to multipath effects. This can be inferred by examining retransmission of frames however this in itself is not reliable due to the fact that the passive external capture point may also miss frames.

Using this passive external capture technique does have uses and advantages. It is cheap and easy to deploy and can be used as a site-survey mechanism during either the design phase or operational phase of the network deployment. It can be used to measure coverage in traditional 802.11 wireless access networks, however it can only infer one-way coverage - from the access point to the measurement point. Passive external capture has the advantage of not requiring changes to the existing network infrastructure, whether hardware or software.

In the context of a wireless wide-area network, where wireless links are used to provide backhaul as well as end-user access, passive external capture falls short. As these networks become larger and more complex, the measurement of self-interaction becomes more important. Additionally, the cost of deploying separate passive measurement nodes increases as the network size increases. This project proposes that by performing measurement at each wireless router in the network at the link-layer - *internal* capture rather than external capture - a far more accurate picture of the physical connectedness of the network can be achieved.

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The internal measurement of the wireless network can be achieved using either passive or active techniques, both of which are suitable for measuring different phenomena in different situations. Our measurement system is entirely software based. It can either be run as a userspace application on its own or it can be additionally augmented with a kernelspace extension which provides more efficient processing of measurement packets. The system is designed to be run on commodity Linux based wireless routers without changes to the wireless medium access control protocols.

The use of internal capture is not an entirely novel idea in itself. Wired networks are often measured this way. However, where this work stands out is that the internal capture is performed on every node in the wireless network, whereas existing literature focuses on external capture, occasionally with multiple measurement points. Additionally, literature that does use internal capture for wireless measurement - for example [2, 1] - generally only focuses on single wireless links, rather than instrumenting the network as a whole.

When the entire network is instrumented in this fashion, an accurate view of the channel conditions can be measured at each receiver. Hence when a frame is transmitted by any node, the measurement system will know exactly which nodes received the frame and the exact channel conditions it was received under. The measurement platform does not need to guess whether a station transmitted a particular frame, nor does it need to perform techniques such as merging wireless traces from multiple external measurement points [5], which ultimately shows which frames were on the air at a given time, but does not accurately reflect the conditions in which they were received, such as signal and noise levels at the receivers.

In support of instrumenting the entire network with measurement is a framework for deploying tests to the network, collecting the measurement data from the network of distributed measurement points and storing it for further analysis. However, this extended abstract will discuss the measurement system itself and its uses, rather than the data collection framework.

2. DISTRIBUTED MEASUREMENT

With an accurate picture of the physical connectedness of the network, several link-layer and physical phenomena can be measured. For example, it becomes trivial to measure the level of cross-channel interference where links on different channels interfere with one another. This is especially useful for a network operator to know as a network grows organically over time.

Active measurement using known frame content provides a view of both the packet error rates, as well as the bit error patterns within a frame, which can be useful information in the design of error correction schemes in future medium access control protocols.

In order to discuss the usefulness of our new approach to wireless measurement, this abstract will use the example of detection of hidden nodes in the network. This is simply one of many applications that distributed link-layer measurement provides, but is a good example of its usefulness in a number of scenarios.

2.1 Using Distributed Measurement to detect hidden nodes

Hidden nodes (or hidden terminals [6]) are wireless nodes that cannot hear each other but wish to transmit a frame to a common node. Because they cannot reliably detect transmissions from each other, collision avoidance through CSMA/CA fails and the probability of frame collision increases dramatically. This affects the available goodput of the network and so detection of hidden nodes in a wireless wide-area network is useful so that operators can take appropriate actions to avoid it, for example, though use of channelisation or MAC layer techniques such as RTS/CTS.

In their 2006 paper [4], Li et. al. propose methods for detection of hidden nodes using active and passive methods. Their methods differ from ours in that their methods actively solicit responses from a node's two-hop neighbourhood in order to detect hidden nodes as needed. Their method is aimed at being implemented as part of a medium access protocol to dynamically avoid hidden nodes, whereas our methods are aimed at being part of a larger network monitoring system.

Detection of hidden nodes can be performed actively, passively or by inference, depending on how much of the network infrastructure is instrumented with measurement. Starting with the best case scenario of having the entire network instrumented, frames with known content can be actively transmitted and each host that receives the frame can record the event. If this is performed in a distributed fashion across the whole network, then a directed graph showing the physical connectivity to and from each host can be generated. By applying a simple traversal algorithm over the graph, nodes that are communicating with common nodes but not each other can be detected. Such nodes are hidden to each other and will potentially cause CSMA/CA failures. It is worth noting that the relationship between the hidden nodes can either be uni- or bi-directional which can affect wireless medium fairness.

Alternatively, the same can be achieved using passive measurement, however this will only find nodes that are actually transmitting frames. The advantage of passive measurement is that it introduces no overhead to the network. As an aside, using active measurement probes allows us to control parameters such as transmitted bitrate. By performing the active measurement for each of the available bitrates, multiple directed graphs can be generated which show physical connectivity at each bitrate. The connectivity at different bitrates changes due to differing signal-to-noise ratios required to correctly decode frames. This additional data can be used to show which links are capable of supporting which bitrates and can be useful in the study and design of bitrate selection algorithms.

In the case where not all of the nodes on the network are able to be instrumented, for example where client premise equipment cannot be instrumented or where overlapping networks are interfering with the network being measured, a process of inference can be used to detect hidden nodes to a certain level of confidence. By determining the inter-frame spacing of received packets and finding instances where the spacing violates the 802.11 Distributed Coordination Function (DCF) specifications it can be inferred that the nodes transmitting the frames are hidden from one another. Work on inference of hidden nodes is an ongoing topic.

3. FURTHER WORK

We are currently in the process of instrumenting a large, production network consisting of both backbone and access links. We hope that by instrumenting the entire network with both active and passive measurement we can not only detect hidden terminals but also gain an insight into other phenomena described above, such as cross-channel interference, packet error rates, etc.

4. REFERENCES

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