Research Statement

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I. Overview

My research focus is in the area of wireless networking. I develop techniques to improve the performance of IEEE 802.11-based (Wi-Fi) wireless networks. In my research, I focus on real and operational Wi-Fi access networks, such as actual deployments of wireless mesh networks and wireless LANs. This entails developing practical and realistic methods and algorithms. My major research is on developing models to characterize interference in such Wi-Fi networks. I use such models to develop algorithms for supporting applications such as video and voice over mesh networks. I have also worked on creating mesh network testbeds, and providing support for seamless mobility for clients in such networks.

II. Summary of Research

A. Interference modeling [2], [3]

Interference in wireless networks causes reduction in network capacity, which in turn may lead to starvation, unfairness, and reduced application performance. Characterizing interference is thus critical to understanding the performance of a wireless network. Many protocol and algorithmic work fundamentally depend on such characterization. However, the interference models used in current research are either over-simplified, or too abstract with unknown parameters limiting their use in practice. I use simple measurements from networks to develop realistic and accurate models of interference. In my research, I have looked at three different ways to model interference, and its impact on network capacity, which I describe in the following.

a) Using active measurements: I develop a practical, measurement-based model to estimate the capacity of any given link in the presence of any given number of interfering links in an actual deployed 802.11 network, carrying any specified amount of offered load. For a network with N nodes, only O(N) measurement steps are needed to gather metrics for individual links (received signal strength) that seed the model. These measurements are used to model the 802.11 physical layer behavior of deferral and collision, which are input to a markov model we have developed to capture the 802.11 MAC layer behavior. We provide two solution approaches to solve this coupled model: one based on direct simulation (slow, but accurate), and the other based on analytical methods (faster, but approximate).

b) Using simulations: I also show that as a by-product of above research, we can create a highly accurate simulation model (e.g., using a packet level simulator such as ns2) of a real deployed network by seeding the simulator with measurement data to accurately model the 802.11 physical layer.

c) Using passive monitoring: The above modeling approaches require active measurements. Also, they require instrumentation access to network nodes. These could be impractical in many deployment scenarios. To address this issue, I develop an approach to estimate the interference between nodes and links in a live 802.11 network by passive monitoring of wireless traffic using a distributed set of sniffers. I model the 802.11 protocol interaction between a pair of transmitters as a Hidden Markov Model (HMM), and use a machine learning approach to learn the state transition probabilities in this model using the observed wireless traffic traces. This in turn helps us to deduce the interference relationships.

B. Applications: VoIP on Wireless Mesh Networks [4], [6]

In an application of the above-mentioned capacity model, I address the issue of supporting voice-over-IP (VoIP) calls in a wireless mesh network. Specifically, I propose solutions for call admission control (CAC) and route selection for VoIP calls. Call admission decisions are made by using the capacity model to predict whether the capacity constraints at various nodes will be satisfied if a new call is admitted with a given route. I also develop a polynomial-time algorithm to search for feasible routes. In addition to studying feasibility, I study several routing metrics such as shortest feasible path and maximum residual feasible path.

C. Wireless Mesh Networks [5], [1]

I earlier designed iMesh, an infrastructure-mode 802.11-based mesh network. Here, 802.11 access points double as routers making the network architecture completely transparent to mobile clients, who view the network as a conventional wireless LAN. Layer-2 handoffs between access points trigger routing activities inside the network, which can be thought of as layer-3 handoffs. We implemented iMesh on a testbed, and evaluated handoff performance. The overall handoff latency varies between 50-100 ms, depending on different layer-2 techniques, even when a five-hop long route update is needed. This small latency is conducive to interactive and delay-sensitive applications such as VoIP.

III. Future Research

A. Wireless network performance

I envision that interference in Wi-Fi networks will be an ever increasing problem in Wi-Fi networks due to the rapid growth of wireless LAN and mesh network deployments. Interference can be mitigated in such networks by proper assignment of radio resources, such as, channel, transmit power, and antenna direction. However, these resouces are limited, and the increasing density of networks ensures that interference cannot be eliminated.

My work on interference modeling has several applications in improving network performance, which I would like to work on in future. Interference models can be used for better radio resource management, for capacity planning, and for deploying new Wi-Fi networks. My current research can also be very useful for managing wireless networks. The interference modeling approach can be used to readily build a conflict graph of the network, or identify regions of starvation. A network administrator can then use such tools to identify problems in network deployments and correct them using appropriate resource management.

B. Vehicular Wi-Fi

Communication among vehicles, and between vehicles and road-side infrastructure, has several applications, such as propagation of traffic information, sensing applications, and in-car entertainment. Due to its widespread deployment in urban areas, Wi-Fi is a powerful medium for such communication. This has been shown in recent literature using several viability studies. However, vehicular Wi-Fi poses several challenges not common to conventional networks. Due to the mobility at high speeds, the sessions of connectivity are typically short, and are characterized by frequent disruptions. This severely impacts the attainable throughput, and makes session-oriented applications infeasible.

I am currently working on a project where the goal is to optimize the handoffs performed by a vehicle as it drives by roadside Wi-Fi access points (APs). We utilize the notion that people are creatures of habit, and drive through familiar routes in familiar fashion everyday. Thus, there is a high degree of predictability in people's mobility, and their Wi-Fi connectivity along their most common routes. We use this to reduce the connection establishment latency by preparing a client to handoff even before it reaches an AP, and to pre-compute the handoffs to be performed along a route. During the course of my current work, I have found vehicular Wi-Fi to be a fascinating area to work on, and I would like to do more research in future in this area as there are several other problems to solve.

C. *Software defined radio*

Recently, software defined radios (SDRs) have become an important platform for doing physical and MAC layer research in wireless networking. My work on interference modeling can gain particularly using such devices, as it can be used to experimentally evaluate any algorithms developed at the MAC layer to reduce interference. An example of this is a scheduling algorithm when using TDMA. Off-the-shelf Wi-Fi hardwares do not provide the ability to make any changes at the MAC layer, while it will be possible to do so in an SDR.

I would also like to use an SDR to experimentally evaluate the impact of physical layer parameters. I have conducted analytical and simulation-based evaluations earlier to show that splitting 802.11 channels improves capacity as bandwidth-independent overhead remains constant, while contention is reduced. I would like to experimentally validate such hypothesis using SDRs.

REFERENCES

[1] Samrat Ganguly, Vishnu Navda, Kyungtae Kim, Anand Kashyap, Dragos Niculescu, Rauf Izmailov, S. Hong, and Samir R Das. Performance Optimizations for Deploying VoIP Services in Mesh Networks. *IEEE Journal on Selected Areas in Communications*, 24(11):2147–2158, Nov. 2006.

[2] Anand Kashyap, Samrat Ganguly, and Samir Das. A measurement-based approach to modeling link capacity in 802.11-based wireless networks. In *ACM MobiCom*, Montreal, September 2007.

[3] Anand Kashyap, Samrat Ganguly, and Samir Das. Measurement-based approaches for accurate simulation of 802.11-based wireless networks. In *MSWIM*, Vancouver, October 2008.

[4] Anand Kashyap, Samrat Ganguly, Samir Das, and Suman Banerjee. Voip on wireless meshses: Models, algorithms and evaluation. In *IEEE Infocom*, Anchorage, Alaska, May 2007.

[5] Vishnu Navda, Anand Kashyap, and Samir R. Das. Design and evaluation of iMesh: An infrastructure-mode wireless mesh network. In *IEEE WoWMoM*, pages 164–170, Taormina, Italy, June 2005.

[6] Hung-Yu Wei, KyungTae Kim, Anand Kashyap, and Samrat Ganguly. On Admission of VoIP Calls over Wireless Mesh Network. In *IEEE ICC*, 2006.