An Optimized Network Design System for Mobile Adhoc Networks

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ABSTRACT

Mobile adhoc networks (MANET) works by taking a specification of network requirements and objectives, and allocates resources, it satisfies the input constraints and maximizes the communication performance objectives. It explores power control, flow control, scheduling, mobility and uncertainty in the communication channel models. In this project, an efficient and reliable control methods has been used in order to meet the requirements with a novel network design algorithm, aggregating existing approaches, and providing a general framework for a network designer to test new proposed resource allocation methods. It has an high-level view of the OMAN architecture, review specific mathematical models used in the network representation, and shows how OMAN is used to evaluate tradeoffs in MANET design for power consumption. While simulation is an important part of measuring the effectiveness of implemented optimization techniques, the novelty and focus of OMAN is on proposing novel network design algorithms, aggregating existing approaches, and providing a general framework for the network design to test out the resource allocation methods.

Keywords - Mobile adhoc Networks, Robust Power Control, Routing protocol, Resource allocation, Throughput.

1. INTRODUCTION

The increasing progress of wireless local area networks has opened new horizons in the field of telecommunications. Among the various network architectures, the design of mobile ad hoc network (MANET) has attracted a lot of attention. A MANET is composed of a set of mobile hosts that can communicate with one another. No base stations are supported in such an environment, and mobile hosts communicate in a multi-hop fashion. In developing the Optimization for Ad hoc Networks (OMAN) system, the main goal is to bring together network resource allocation problems and the methods for solving them into a cohesive, extendable, object oriented software package with a standard application programming interface (API) and graphical user interface (GUI).

Mobile ad hoc networks are self conjuring multi-hop wireless networks and self organizing where, the structure of the network changes dynamically. This is mainly due to the mobility of the nodes. Nodes in the networks utilize the same random access wireless channel, cooperating in a friendly manner to engaging themselves in multi-hop forwarding. The node in the network not only acts as hosts but also as routers that route data to/from other nodes in network. The main limitation of ad-hoc systems is the availability of power. The disadvantage of ad hoc network is that the nodes should be in the range of a base, so that these nodes can receive the information and transmit its for further devices.

2. OMAN NETWORK DESIGN

OMAN is a process of optimizing variables in a well defined scenario across time, space and the communication network stack. It defines a portfolio of objectives which include, power, capacity, connectivity, survivability, delay, fairness, load balancing, throughput and redundancy. Network design, like other broad optimization fields, is often treated as a collection of distinct problems with significant effort focused on finding the solutions to each of those individual problems. An ad hoc network is a collection of mobile hosts forming a temporary network without the aid of any stand alone infrastructure of centralized administration.
Fig. 1 High level dataflow in OMAN

Inputs are the scenario specification and optimization variables and objectives, as well as an extensive set of parameters defining every aspect of the network model, simulation, and optimization. In other words, the system input is the definition of the design problem and a list of directives on how OMAN should find a good solution to this problem. The output of the system is a set of optimal or locally optimal resource allocations and an estimate of the performance expected when the network operates under those design decisions. A MANET is made up from a set of MANET routers, these routers and maintains a routing structure among themselves over dynamic wireless interfaces.

The generally accepted network design cycle consists of three steps:
1. Developing a network model,
2. Estimating the performance of the proposed network through simulation,
3. Manually tweaking the modal parameters until an acceptable performance is achieved for the target set of scenarios.

The estimation is usually done with network-specific discrete event simulators such as Qualnet or Opnet. In addition, existing design tools aid in well-defined specialized aspect of the resource allocation problem. This tool is used to show the network the best locations for access points by using the predictive algorithms and propagation modeling based on geographic topology.

The performance of a proposed design is analyzed through simulation, and changes to the model are made until the model behaves as desired. However due to the complexity of networks and the large number of design parameters, changes of the model may have an unintended effects which must then be accounted for. To alleviate the timely process of designing and redesigning a network, we intend to apply optimization theory to generalized networking models in order to efficiently design MANET.

3. SOFTWARE ARCHITECTURE

3.1 TWO LEVELS OF USER INTERFACE

OMAN has two distinct forms: an application with a graphical user interface and a library with an application programming interface. The former is an interface for human users (e.g., network design), while latter is an interface for other programs that link against it. The rest is handled by OMAN through its API without the user having to know any implementation details of the simulation and optimization algorithms. The rest is handled by OMAN through its API (after converting the Opnet network data structures to those OMAN).

One of the goals of OMAN as a network design tool is to provide a mechanism for comparing network technologies, i.e., radios, MAC protocols, routing protocols, and battery models. Each such model or algorithm is implemented in OMAN in a modular way such that it can be swapped out for any number of alternatives.

The GUI provides a streamlined way of configuring multiple alternatives, and comparing them through concurrent simulation and optimization. An “internal developer” can extend OMAN by providing an implementation of a new alternative model or algorithm. The AP supports such an extension without needing to be modified. The developer only has to add a set of control parameters associated with the new extension. These parameters are then automatically added to the GUI through active generative programming.

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The four network design paradigms under which OMAN operates are the two distinguishing characteristics are:
1. whether the resource allocation has a temporal dimension and
2. Whether the optimization is performed in a centralized or distributed fashion.

The resources which are to be efficiently allocated on an ad hoc wireless network are naturally distributed, residing either on the nodes or the edges of the graphs that represent the network state. The algorithms in OMAN are separated into two categories: centralized (network centric) and distributed (node centric). The former operates on single “snapshots” or on a time-averaged model of the global network state. The latter operates as a control mechanism on the node. To allow for asynchronous control decisions on the nodes, OMAN provides a full-fledged discrete event simulator.

The static and time averaged paradigms view the network as a whole, and efficient resource allocation as a global decision process. The event-based reactive controller and robust planner move the decision process to each individual node. The distinction within each pair is whether the result of the optimization has a temporal dimension.

The distinction between distributed versus centralized and event based versus slotted algorithms is orthogonal to another critical parameter: the completeness, certainty, and reliability of information available to a node or network in performing the efficient resource allocation. The network model and the discrete event simulator operating on the model have perfect information about the past, present and future of network state. The degree to which that information is available to the nodes is controlled by the “information filter”.

3.2 DATA STRUCTURES AND ALGORITHMS

OMAN can be logically separated into three types of classes: those that store data, those that process data, and those that integrate the two into a cohesive simulation and optimization system. Specifically, the three categories of classes are:

Data Structures
Objects such as the graphs which represent the current and past states of the network, including resource allocation decisions, packet transmissions, channel conditions, movement paths, etc.

Algorithms
A modular collection of encapsulated functions which process the object data. These include classes that optimize the resource allocation decisions across the network stack, visualize the network state, convert, aggregate, and integrate available information into a form accepted by other algorithms.

Directors
The “glue” classes that control which algorithm gets executed when and on what data. Depending on the network design paradigm, this involves everything from a simple class that evolves the position of the nodes as some aspect of the network is optimized to a full-blown event-based simulator which controls every possible decision and change affecting the network state using an arbitrarily expandable set of events.

4. NETWORK MODEL OVERVIEW

It uses the Physical and MAC model abstraction similar to the one end and the specified, scheduling is done in the time domain, where the transmissions are synchronized. The choice of transmitters with associated powers, and the set of schedules form a period of concurrent slotted transmissions which are looped continuously. It uses a random packing procedure that picks a set of schedules that guarantee each node at least one chance to transmit and guarantee concurrent transmitters each succeed.
The control parameters of the PHY graph are the power on each node and the minimum acceptable signal-to-interference-plus-noise ratio which defines the quality-of-service requirements for the channels. The network models in OMAN vary in the resolution of their abstractions and the restrictiveness of their constraints. The benefit of these abstractions in simulation is the tractable interpolation of resource allocation performance, often in real time. Their cost is the potential inaccuracy of those interpolations as predictors of real-world system performance. For this reason, a major part of the effort in building OMAN is validating simulation results with measured testbed data.

The MIMO channel in OMAN was simulated using the full correlation channel modeling technique, where the correlation matrix of each link was estimated from measured data. The measurement and simulation of Shannon capacity for each of the links individually and for the sum capacity of the network.

In the idealized slotted aloha model that we are considering here, time is slotted and all packets are of equal length. Packet transmission time is one full slot. Packets are transmitted in the next slot after they arrive. We also assume that there is no buffering, i.e., it is never the case that a station has more than one packet to transmit in a single slot. If that is the case, the station has to buffer one or more packets for later transmission. To accommodate the “no buffering” assumption, we assume that there is infinite number of stations and that each new arrival happens at a new station. Note that in the absence of the “infinite stations” assumption, we have to model packet buffering at each node. This is what will happen in a real implementation; but this will complicate the analysis.

If more than one station transmits packets in the same slot, there is a collision, and the receivers cannot receive the packets correctly. Successful transmission happens only when there is exactly one packet transmitted in a slot. If no packet is transmitted in a slot, the slot is called idle. Assume that there is an immediate feedback from the receiver about the status of each transmitted packet (i.e., correctly received or not). This feedback is not modeled within our description of the slotted aloha protocol. But in case of a collision, the colliding packets are retransmitted at a later slot after a randomly chosen backoff period. However, since future network lifetime is practically difficult to estimate, the next three metrics have been proposed to achieve the goal indirectly. Variance of residual battery energies of mobile nodes is a simple indication of energy balance and can be used to extend network lifetime. Cost-per-packet metric is similar to the energy-per-packet metric but it includes each node’s residual battery life in addition to the transmission energy. The corresponding energy-aware routing protocol prefers the wireless link requiring low transmission energy, but at the same time avoids the node with low residual energy whose node cost is considered high. With the last metric, each path candidate is annotated with the maximum node cost among the intermediate nodes (equivalently, the minimal residual battery life), and the path with the minimum path cost, min-max path, is selected. This is also referred to as max-min path in some protocols because they use nodes’ residual battery life rather than their node cost.

4.1 POWER CONTROL MECHANISMS

The selection of sufficient transmit power level by a node during its communication with its neighbors is termed as power control in ad hoc networks. The algorithm related to power control utilizes lowest possible transmit power level that will offer reliable communication between peers. To maintain network connectivity and avoid network partitioning and to provide power efficient operation are the main objectives of power control in MANET. The two ways of minimizing energy consumption in MAC protocol design are as:

Power saving mechanisms: It allows a node to enter a doze state by powering off its wireless network interface whenever possible.

Transmit power control scheme: It uses carefully controlled transmit power level to reduce energy consumption.

The power control method deals mainly with localized algorithms. In localized algorithms, the nodes in the network make routing decisions based solely on the location of itself, the location of the destination and the location of its neighbors. Localized algorithms are distributed algorithms where simple local node behavior achieves a desired global objective. Non-localized algorithms are those in which the nodes require the complete knowledge of all the nodes in the network along with the corresponding edges.

The scenario generator also creates a set of packets, each with a source node, destination node and time, from some statistical network traffic specifications. Throughout a genetic algorithm run, we use a single scenario generated prior to the run. This scenario plus predefined RF propagation profiles and interference models provide a set of inputs to the simulator that are the same for each execution. Here, differences in the performance are due solely to different values for the parameters.

Some are based on quality of service, such as dropped packets and transmission delay while others are not directly tied QoS, such as power consumption rate. Hence, our problem is an example of a multiojective optimization problem. There are a variety of different techniques for
using genetic algorithms for multiobjective optimization. The simplest and most common, create a single objective function as the weighted sum of multiple objective criteria. Selection of the values of the weights provides an explicit tradeoff between the different criteria available.

4.2 ROUTING PROTOCOLS

Routing protocol specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network, the choice of the route being done by routing algorithms. Each router has a priori knowledge only of networks attached to it directly. A routing protocol shares this information first among immediate neighbors, and then throughout the network.

The routing protocols proposed for MANET are generally categorized as table-driven and on-demand driven, based on the timing of when the routes are updated with the table-driven routing protocols, each node attempts to maintain consistent, up-to-date routing information to every other node in the network. This is done in response to changes in the network by having each node update its routing table and propagate the updates to its neighboring nodes. Thus, this proactive in the sense that when a packet needs to be forwarded, the route is already known and can be immediately used.

In the case for wired networks, the routing table is constructed using either link state or distance vector algorithms containing a list of all the destinations, the next hop and the number of hops to each destination. Many routing protocols including Destination Sequenced Distance Vector (DSDV) and FSR protocol belong to this category and differ in the number of routing tables manipulated and the methods used to exchange and maintain routing tables.

Classification of routing protocols in MANET’s can be done in many ways, but most of these are done depending on routing strategy and network structure. According to the routing strategy the routing protocols can be categorized as Table-driven and source initiated, while depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing.

Reactive and Proactive Protocols are the routing protocols that are used in mobile Ad hoc networks to send data from the host to the destination. A packet data is sent from source to destination in an Ad hoc network through multiple nodes that are mobile. This type of network is generally used in a disaster hit area, military field or in space where fixed infrastructure is destroyed or does not exist.

4.3 SIMULATION ENVIRONMENT

In ad hoc mobile networks, nodes are moving at all times and there may be several nodes exiting and entering the network at any given point of time. To keep a track of all these nodes and their corresponding edges is cumbersome and requires a huge overhead. In contrast to simply establishing correct and efficient routes between pair of nodes, one important goal of a routing protocol is to keep the network functioning as long as possible.

Transmission power control and load distribution are two approaches to minimize the active communication energy, and sleep/power down mode is used to minimize the energy during inactivity. Before presenting protocols that belongs to each of the three approaches, energy related that have been used to energy efficient routing path instead of shortest one are available.

The first metric is useful to provide the minimum power path through which the overall energy consumption for delivering a packet is minimized. Here each wireless link is annotated with the link cost in terms of transmission energy over the link and the minimum power path is the one that minimizes the sum of the link costs along the path. However a routing algorithm using this metric may result in unbalanced energy spending among mobile nodes. They are:

- Energy consumed/packet
- Time to network partition
- Variance in node power levels
- Cost/ Packet and
- Maximum node cost

Fig.5 Classification of Routing Protocols In Mobile Ad-hoc Networks
When some particular mobile nodes are unfairly burdened to support many packet relaying functions they consume more battery energy and stop running earlier than other nodes disrupting the overall functionality of the ad hoc network. Thus, maximizing the network lifetime is a more fundamental goal of an energy efficient routing algorithm: given alternating routing paths, select the one that will result in the longest network operation time.

Fig.6 Minimizing Probability of violating the SINR requirement and minimizing the total transmit power

Allocation of physical resources (e.g., transmission power) based on knowledge of the network state is often complicated by the presence of uncertainty in the available information. Therefore, when the characteristics of the wireless propagation channel are highly dynamic or only noisy measurements are available, the problem of optimally allocating resources under such a statistical representation of the channels can be solved in OMAN by assuming the distribution mean for each channel state, or by using a Robust Optimization (RO) method which seeks to quantify the dependability of the resource allocation solution. A fundamental problem in RO is the tradeoff between feasibility and optimality. RO may be interpreted to be a multiobjective optimization problem with two objectives: maintain feasibility and seek optimality. With this view in mind, a Pareto front can be constructed to demonstrate the tradeoff between the two objectives. A network designer then only provides OMAN with 1) the requirement of sufficiently high feasibility or 2) a ceiling for the transmission power on the network.

5. CONCLUSION

Thus the network design engine of OMAN was designed for maximizing the performance of communication that exists between the different resources allocated in the network. While simulation is an important part of measuring the effectiveness of implemented optimization techniques, it was done successfully for the needs of better performance of an optimized mobile ad-hoc network. A typical network simulator encompasses a wide range of networking technologies and can help the users to build complex networks from basic building blocks such as a variety of nodes and links was achieved by using the Mobile ad-hoc network.

REFERENCES


