WIRELESS LOCAL AREA NETWORK

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1. INTRODUCTION

Context of the Problem

During the past decades wireless communication has increased tremendously. Wireless communication for personal use is, and will continue to be, part of our everyday life. The reason for its success is simple: it enables mobility during communication. The most common form of wireless communication today is the use of cellular phones. In recent years, the development of standards for wireless packet networks, such as wireless local area network (Wireless LAN), has resulted in that manufacturers equip everything, from powerful laptops to small embedded devices, with hardware support for different radio technologies. This has increased the popularity of wireless packet networks both in industry and in home networking.

Both the mobile telephony network and Wireless LANs are examples of so called infrastructure-based wireless networks. This means that there has to be a pre-existing network infrastructure for these networks to be functioning. Such network infrastructures typically consist of fixed positioned base stations or access points with wire-lines connecting them to a backbone network. The wireless nodes in these networks do not talk directly to each other. Instead, each node is connected to a base station through which it communicates with other nodes.

Infrastructure-less wireless networks are usually called multi-hop wireless mobile ad hoc networks. In the rest of this paper we will use the term ad hoc network. “Ad hoc” often means “improvised”, or “for the needs of the moment”. (Siva Ram Murthy & Manoj). In computer networking, we think of an ad hoc network as a wireless network without any pre-existing infrastructure. Such networks have no base stations, access points, or wire-line backbone network. Instead, the nodes themselves constitute the network and communicate directly with each other. Most work within ad hoc networking, as well as the work in this paper, use (or assume) the wireless LAN standards of IEEE 802.11 as the underlying technology.

Statement of the Problem

The theme of this paper is experimental evaluation of ad hoc routing protocols. Our goal is to assess ad hoc routing protocols’ strength and weaknesses through real world routing protocol evaluations. In contrast to simulations, experimental studies need to handle inherent stochastic factors like the radio environment and node mobility. Simulation is a valuable tool for evaluating ad hoc routing protocols. Simulations are easily repeatable, which makes comparison of different routing protocols straightforward.

Furthermore, they facilitate evaluation of routing protocols in different networking contexts by varying parameters like test area size, number of nodes, mobility pattern and data traffic pattern. However, simulation is based on (simplified) models of reality. The problem is that simulations can not capture the effects of the inaccuracies of their own models. Therefore, we believe that it is important to complement simulation studies with experimental studies.

Research Questions

Conclusive comparisons and parameter explorations are possible only if repeatability of measurements is addressed. Therefore, the main problem for real world evaluations is:

• How can we make real world ad hoc routing experiments repeatable? Our approach was to design and build a testbed that can handle and assess repeatability. A related problem concerns test-run execution and how to orchestrate experiments with severeal dozens human participants. Complex testbed handling, such as installation, configuration and execution can negatively affect test-run management and scalability, and easily introduce systematic errors between test-runs. The next problem addressed is:

• How can we design and build a test environment such that it supports easy manageable and scalable real world testing of ad hoc routing protocols? Given that we can accurately repeat real world test-runs, it becomes interesting to compare our findings with simulation results. The final problem addressed is:

• How can we identify and capture the impact of real world effects that are not visible in simulations?

Significance of the study

The selection of problems presented is based on our view of which areas should be prioritized in order for ad hoc networking to be accepted as a usable technology and thus be deployed on a larger scale.

• Routing. Ad hoc routing protocols must address: dynamic topology changes due to mobility, the error prone wireless channel, limited bandwidth of a wireless shared channel, limited electrical power supply and limited computationally capabilities of nodes.

• Experimental evaluations and practical experience. Simulations can never completely replace practical experience. Implementation and experimentation reveal behavior that might not be experienced when performing simulations. Practical experience generally gives a better understanding for system integration and configuration issues. (Anastasi et al.)

• Self-configuration. Self-configuration, or at least partial self-configuration, is necessary if ad hoc networks are to be successfully deployed on a large scale. In ad hoc networks address configuration becomes harder due to the lack of centralized network services.

• Internet connectivity. Although ad hoc networks per se do not rely on any pre-existing infrastructure, one important property in many potential usage scenarios is connectivity to fixed networks, such as the Internet. In such cases one or more nodes act as gateways and share the fixed network connection with the other ad hoc nodes.

• TCP performance. The performance degradation of TCP in wireless networks is a well-known problem. Designed for the wired domain, TCP assumes that all packet losses are due to congestion and therefore TCP decreases the transmission rate in case of a perceived packet loss. Wireless networks have a higher rate of packet loss due to the error-prone wireless channel. (Yu)

• Security. Interest in the area of security has increased lately and efforts have been spent on identifying security threats together with counter-measures. Wireless networks make it easy to perform eavesdropping, denial of service and impersonation attacks. In ad hoc networks nodes can join and leave as they wish. This enables malicious nodes to easily infiltrate the network, and for example attack scarce resources by consuming bandwidth or draining other nodes' batteries. (Molva and Michiardi)

• Energy and Power Management. Battery power is a limited resource in ad hoc networks. The two main approaches to conserve energy are power-save protocols and power control protocols. A node's energy consumption is closely related to the time the network interface card spends in non-sleeping mode (Feeney and Nilsson). Power-saving protocols therefore aim at minimizing this time, without significantly affecting the overall network performance.

Research Methodology

The research presented in this paper is carried out with an experimental approach. An experimental approach is typically applied when theoretical analysis is inadequate or infeasible. The basis is always existing knowledge, but the starting point can vary. For example, it can be to apply and explore existing solutions to a new area, or a concrete problem that needs to be solved, or an observation of unexpected system behavior that needs further investigation. The starting point raises one or more questions, which then are formulated into one or more hypotheses.

The next step is to design an experiment that will test the hypotheses for validity. During the experiment measurement data is collected. In the analysis phase that follows it is important to first ensure that the experiment tested the desired properties and that the result is conclusive. If this is the case, we can either validate or invalidate the hypothesis. It is important that experiments are repeatable and results reproducible. Repeating a wireless network measurement exactly is impossible, fundamentally because the radio medium is dynamically changing with time. Node mobility is another stochastic factor in real world ad hoc routing experiments. A central issue in this paper is to develop and use a methodology that addresses repeatability.

We deal with stochastic factors in the following way: (1) We identify the factors, (2) we avoid some of them by a careful design of the testbed, (3) for the remaining factors we design the testbed and the methodology for a low variance, and (4) finally we include monitoring of the factors during an experiment in order to assess the variance and impact on the conclusiveness of the results. A systematic approach is needed to efficiently and conclusively explore the parameter space of an ad hoc routing protocol. However, the parameter space is often large and experiments are usually costly both in terms of time and man-power. Therefore, although being systematic, the real challenge becomes to judge which parameters to explore and assign values to the parameters that will not be explored throughout the experiment.

2. REVIEW OF THE LITERATURE

Research in ad hoc networking is expanding rapidly. Al least five years ago different papers on ad hoc networking were relatively uncommon. Today, this topic is included in almost every major networking paper, and there exists more than ten international conferences or workshops as well as several journals explicitly targeting ad hoc networking. The challenges and topics presented above are not an exhaustive list, but a selection based on those areas we believe will need most urgent focus to increase the usefulness of ad hoc technology.

It is the task of the routing protocol to create and maintain routes to other nodes. These routes should be loop-free and as reliable and durable as possible. A routing protocol uses a distributed algorithm to acquire and maintain route information. Conventional routing protocols used in wired networks were not designed with the specific requirements of ad hoc routing protocols in mind, and unfortunately do not work satisfactorily in ad hoc networks. The key problem with both RIP (Malkin) and OSPF (Moy) is their slow convergence to a consistent topological view of the network. For example, when the network topology changes, new information has to be propagated through the whole network before it can be considered to be in a correct state. In RIP, each router must recompute its distance vector before it can pass on the new route information.

Furthermore, RIP suffers from the count-to-infinity problem (Perlman). Both these issues have a severe negative effect on the convergence time. In OSPF, although link-state information can be disseminated before route recomputation, the propagation of this information slows down convergence. In addition, considering the limited resources of an ad hoc network, both these protocols generate a lot of redundant information that consumes bandwidth in a unnecessary way. In a wireless network bandwidth is more expensive and transmission is minimized since it drains the battery power. (Siva Ram Murthy & Manoj).

Routing Strategies for Ad hoc Networks

Ad hoc routing protocols are commonly classified into proactive, reactive and hybrid, based on how they update routing information. The concept of proactive routing means that all nodes (i.e., routers) exchange route information periodically, or whenever the network topology changes, in order to maintain a consistent, complete and up-to-date view of the network at all nodes. Each node uses the exchanged route information to calculate the costs (e.g., number of hops) to reach all possible destinations. Optimized Link State Routing (OLSR) and Topology Broadcast Reverse Path Forwarding (TBRPF) are two examples of proactive routing protocols. (Siva Ram Murthy & Manoj).

Reactive routing is generally not dependent on exchanges of periodic route information and route calculations. Instead, whenever a route is needed the source node has to perform a route discovery (disseminate a route request throughout the network and wait for a route reply) before it can send any packets to the destination. The route is thereafter maintained until the destination becomes inaccessible or the route is no longer needed. Examples of reactive protocols are Ad hoc On-demand Distance-Vector (AODV) and Dynamic Source Routing (DSR) Hybrid approaches combines the proactive and reactive approaches, for example, the Zone Routing Protocol (ZRP) and LUNAR. Ad hoc routing protocol classifications can be found in (Siva Ram Murthy & Manoj).

3. CONCLUSION

The three major techniques for experimental evaluation of ad hoc routing protocol, simulation, emulation and real world experimentation, co-exist and complement each other. Simulation has been the most commonly used tool since it enables repeatability, parameter exploration and scalability. The main drawback is that the simulator can never capture the effect of its own limitations. Emulators enable part of the test subjects to run as real systems. Most emulators enable repeatability through controlling radio propagation. Recent work reports on advanced emulation of the wireless channel, however as with simulators, they can not capture the effect of inaccuracies in their models. Although some emulators can run large-scale experiments, their scalability is limited by hardware constraints. These hardware constraints, like use of a specialized signal processor, limit the network configurations possible. (Anastasi et al.) Real world experimentation can capture the effect of the stochastic nature that the ad hoc protocols will be subjected to when deployed. The main challenge for real world experimentation is to achieve test repeatability.

The approach of running trace-based simulation/emulation provides realism to these two evaluation techniques since it uses traces from real world measurements. The availability of systems for trace-based execution of ad hoc networks is limited, however. It is important to realize that different evaluation techniques are best suited for different configurations and protocol properties. For example, simulators are appropriate for parameter exploration and large-scale network settings. Emulators let us study the test subject in a real system and can scale up to its hardware constraints. Real world experimentation let us study the effect of the stochastic environment that the system is exposed to. Such experiments allow us to capture effects not visible in simulators or emulators, and to validate the models and assumptions used in simulation and emulation.

4. RECOMMENDATION

The ability for the ad hoc nodes to adapt their routing algorithms to changing network conditions at run-time is the main benefit with running active ad hoc nodes. However, security solutions need to exist and be deployed before it is realistic to believe that an active networking approach will get acceptance outside "closed group" ad hoc networks. Furthermore, until we better understand how to adapt to specific changing conditions, the benefit of such an ability will be limited. On the other hand, with increased networking complexity in the future the need for advanced self-configuration solutions will increase. Active networking provides a powerful concept for such solutions.

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