Simulation Study on Large Scale Wireless Networks

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I. Introduction

A. What is Ad Hoc?

AD hoc is a Latin phrase which means ”for this purpose”. It generally signifies a solution that has been custom designed for a specific problem or task, is non-generalizable, and cannot be adapted to other purposes. Common examples are organizations, committees and commissions created at national or international level for a specific task, or in other fields the term may refer for example to a tailor-made suit, a handcrafted network protocol or a purpose-specific equation.
The former form of the ad hoc is Packet Radio Network . The research of the Packet Radio Network comes from the requirement of the military communication. In the 1972, DARPADefense Advanced Research Project Agencyof the US have begun the research of PRNET (Packet Radio Network) to study the use of Packet Radio Network in the environment of war. After that DAPRA started another research SURAN (Survivable Adaptive Network) to improve the net to be a large scale one. IEEE802.11 standard committee which is set up in the 1991 takes ”ad hoc network ” to describe this special wireless mobile network.
There are two variation of mobile wireless communication networks. The first is known as mobile cellular networks ,which is infrastructure-based , and the second is known as mobile ad hoc networks , which is infrastructure. we can easily find the difference between the two kinds of networks. A mobile cellular network consists of an array of radio cells in which communications in each of the cells is handled by a base station. Thus, the base station is the fixed infrastructure which performs centralized administration. Mobile stations with the footprint of a base station directly communicate with that base station which, in turn, forwards traffic to designated destinations. Thus, among other tasks, the base stations assume the role of a router. A system with a fixed infrastructure is basically a two-hop system. Infrastructures mobile networks are commonly known as ad hoc networks. Ad hoc networks have no fixed routers and no base station. Instead, devices discover others within range to form a network for those computers. Devices may search for target nodes that are out of range by flooding the network with broadcasts that are forwarded by each node. Connections are possible over multiple nodes (multihop ad hoc network).

B. Why Ad Hoc?

The ad hoc network is a kind of special wireless mobile network . All nodes in the net are equal to each other , there is no central , no control node , and the node in the net is powerful , not only can act the role of the mobile end but also can do the work of transmitting the information . Compare with other mobile network , the ad hoc have these characteristics:

1) Infrastructureless. Ad hoc has no base stations, any node can join or quit the network freely. One node’s problem can not affect the whole net. So it cannot be easily destroyed.
2) Self-organized. Ad hoc networks need not depend on any external settings. Nodes can organize a network quickly according to the protocols.
3) Multi-hop routers. If the node wants to send the message to other nodes out of the coverage of the network, it needs multi-hop. Unlike the plain networks, the ad hoc do not rely on the specialized router settings, multi-hop of the ad hoc net is done by the plain node. That means in an ad hoc network there are no routers, but routers are everywhere.
4) Dynamic topologies. Ad hoc network is capabale of high MS mobility.

These Characteristics made ad hoc networks different from the other networks in the structure, organization, and the protocols. So this kind of network has special applications:

- For military. This is the main arena of the ad hoc. Because the ad hoc need no center node, no external net settings, and hard to be destroyed, it plays an important role in the commanding and communications during a combat.
- Sensor network. Sensor network is another important area where ad hoc network is used. in the situations where only wireless net could work, the sending power is limited by the battery energy and other factors, ad hoc is a perfect solution. Nowadays, this technology is popular in investing the explosive.
- For emergency use. When earthquake, storm, or other catastrophe happens, many communication facilities such as UTP wire and the base stations of the cellular networks are destroyed. At this time, the communication depend on ad hoc networks which need no fixed facilities.
- For Personal Area Network(PAN). Ad hoc network can also realize the communication between the PDA, cell phone and the computer, and organize them into a whole network . The Scatternet of the blue-tooth is a typical

example .

- Combination with the mobile communication system.Ad hoc can combine with the mobile cellular networks, using the multi-hop to enlarge the coverage of the mobile cellular networks and to enhance the data transmission rate.

C. How does Ad Hoc Work?

Mainly there are two types of ad hoc routing protocols: (a)table-driven and (b)source-initiated or demand-driven.

1) Table-Driven Routing Protocols: The table-driven routing protocols tries to maintain consistent, up-to-date routing information from each node to every other node in the network. Each node is required to maintain one or more tables to store routing information. The table maintained by each and every mobile node in the network contains all of the possible destinations and the number of hops to each destination in the network, thus, once a MN(mobile node) wants to communicate with a CN(corresponding node), it will search its own memory (the table)to get the effective path to be in touch with CN, through the path, they two can communicate.

It is quite suitable for creating ad hoc networks with small number of nodes, however, it requires a regular update of its routing tables, which uses up battery power and a small amount of bandwidth even when the network is idle and whenever an old node is deleted or a new node is added, it is really troublesome to update the table in each node. Thus, it is not suitable for highly dynamic networks.

2) Source-Initiated on-Demand Routing: The source-initiated on-demand routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process with the network. This process is completed once a route is found or all possible route permutations have been explored. Once a route has been established, it is maintained by a route maintenance mechanism until either the destination becomes inaccessible along every path from the source or until the route is no longer needed. When a mobile node has a packet to send to some destination, it first consults its route cache to determine whether it already has a route to the destination. If there is a route to the destination, it will use that route to send the packet. Or it will initiate route discovery. It is much more efficient than the above one, and it is so flexible that it is quite suitable for the large scale ad hoc network.

D. Routing and Modeling

Compared with traditional cellular network, in the topological structure of ad hoc network, we don't have base stations for divided areas, which leads to a series problem that the routing algorithm maybe very complex. In cellular network, packages hop from pre located base stations or routers, while in ad hoc the mobile node itself will serve as the router and packages probably will hop many times to reach the other end of the channel.

To solve the problem mentioned above, the first way come to our mind is to set a full routing table to maintain consistent, up-to-date routing information from each node to very other node in the network, which is called Table-Driven Routing Protocols. This is obviously the simplest way.

However there is no lunch free. When the scale of the network is small or the mobile node doesn't move frequently, ok, routing can be done this way quite appropriately. But when the scale grows larger and larger and the mobile nodes moves a lot, the cost of updating routing information will be astonishing.

An example of table-driven routing protocol is Destination-Sequenced Distance-Vector (DSDV) Routing. DSDV is a table-driven algorithm based on the classical Bellman-Ford routing mechanism. The table maintained by each and every mobile node in the network contains all of the possible destinations and the number of hops to each destination in the net work.

The other routing protocols for ad hoc network are called Source-Initiated on-Demand Routing. This routing algorithm creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery within the network. This process is completed once a route is bound or all possible route permutations have been explored. Once a route has been established, it is maintained by a route maintenance mechanism until either the destination becomes inaccessible along every path from the source or until the route is no longer needed.

So we can see, this routing method basically consist of two parts, route discovery and route maintenance. When a mobile node has a packet to send to some destination, it first consults its route cache to determine whether it already has a route to the destination. If there exists a route to the destination, it will use that route to send the packet. On the other hand, if the node doesn't have a route to the destination, it initiates route discovery.

One example of on-demand routing is Dynamic Source Routing (DSR). DSR is just based on the concept of source routing.

After some simple estimate, we can find that when the scale of the network is small like tens of users, both algorithm can do the job without too much difference. However, the source-initiated on-demand routing is much more complex and of course cost much more. But when the scale grows larger and larger, the on-demand algorithm, which is somewhat dynamic, should perform better. As we will study on the scale of about tens of thousand users, the on-demand algorithm becomes our choice in the simulation.

It's a little bit unrealistic to test the ad hoc system in reality, especially when the scale is as large as tens of thousands or more. Computer simulation is a reachable way to the solution of such problems. As the tech of computers developed so far, simulation for a large scale network, which was a complaining topic a few years before, can be done quite satisfactorily. Before simulation related works are discussed, here we'll first discuss about the modeling problems.

/cite1 described the system structure using four sub models, a Terrain Model, a Plume Dispersion Model, an RF Channel Model and a Node Model.

The terrain model is a static map related with the plume dispersion model and RF channel model. I was first puzzled why they bring in the concept of plume dispersion model. In their simulation work, they build the model to study the viability of the wireless sensor network as tools to aid emergency response. And they take a deadly chemical agent leak as an assumption. The plume dispersion model is set to motivate the sensors in the system. This model when working will give out signals to tell where the leak is happening. On the other hand, the RF channel model is just like its name, a model that maintains the information between different parts of the system. As mentioned above, both plume dispersion model and RF channel model can be subject to geography of the terrain.

To start the simulation more easily, we usually use "flat terrain". In such model, the terrain is supposed to be the simplest condition that is both the plume and radio signals can propagate freely in the simulation space.

In ad hoc network, every node in the system will serve as a router, which means the node model will have the ability to process information and deliver them to the right direction during the multi-hopping procedure. We have already discussed the routing protocol of ad hoc, and it is just implemented here. For each node, they should basically perform three functions, sending receiving packets, sensing the environment change and routing. So the node model will just perform this way.

When the plume dispersion model gives a signal to tell the environment change, the node model will sense it and start to package messages. This is the function of the node model serving as a sensor. Then the package will be sent and finally will be received by its destination node. During the transmitting process, every time it hops, the node will have to check the routing table to find the package a best suited path to the destination. Since this procedure is quite complex, an efficient routing algorithm is always considered as the key point for the ad hoc network.

E. More About the Simulation

The NS-2 simulator is a discrete event simulator widely used in the networking research community. It was developed at the University of California at Berkeley and extended at Carnegie Mellon University to simulate wireless networks. These extensions provide a detailed model of the physical and link layer behavior of a wireless network and allow arbitrary movement of nodes within the network. Some of the recently proposed wireless routing protocols (DSDV, TORA, DSR and AODV) are also integrated into NS-2.

Each run of the simulator accepts as input a scenario file that describes the exact motion of each mobile node together with the sequence of packets originated by each node as time progresses.Suppose there is a rectangular simulation area with N mobile nodes. Each node has a position and a velocity and moves around on the topography. The position of a mobile node can be calculated as a function of time and is used by the radio propagation model to calculate the propagation delay from one node to another as well as the power level of a received signal. We call receiver any mobile host receiving a packet. The power level at which the packet is received is compared to two different values:

- the receive threshold (RT);
- the carrier sense threshold (CST).

If the power level falls below the CST, the packet is discarded as noise. If the received power level is between CST and RT, the packet is marked as a packet in error before being captured. Otherwise, if the power level is above RT, the packet is received without errors.

Once the receiver starts receiving a new packet, it checks that its receive state is presently idle, meaning it does not currently process any packet. If the receiver is not idle, one of two things can happen:

- If the power level of the packet already being received is at least 10 decibels greater than the power level of the newly received packet, we assume capture of the current packet, discard the new packet, and allow the receiving interface to continue with its current receive operation.
- Otherwise, a collision occurs, and both packets are dropped.

Consider some mobile node M willing to transmit. Beyond the distance R2, the transmission power level of Ms signal is below the CST. The simulator must compute the mobile nodes that are within this range (so they are affected by Ms signal). Therefore NS-2 simulator checks for every node in the topography that is currently participating in a data exchange whether the power level of Ms signal is above CST or not. This check causes a large number of unnecessary steps that increase the cost of the computation exponentially in N, since a system with N pairs of transmitters and receivers requires that $O(N^2)$ pairwise interactions are computed.

The problems one experiences using NS-2 to simulate large ad hoc networks can be divided into two main types: fundamental problems and system idiosyncrasies. The first type of problems restricts the use of NS-2 due to the very high runtime of the simulator, the second seriously limits the number of scenarios that can be simulated. The old NS-2 could only simulate a network with a scale of < 100 nodes and $100 + m^2$.

Valeri Naoumov and Thomas Gross[2] improved the NS-2 simulator. With the use of the *Grid* and the *List*, memory comsumption is reduced to less than 1% of the original NS-2, and the computational cost is reduced(30 times faster) as well. The NS-2 2.27 and later version included their changes.

A project by Georgia Tech[3], CoC has developed key technologies for parallel discrete NS2 simulation technique with a novel parallel software backplane that enables model reuse from different network simulation/emulation tools, including integration across split protocol stack. On a 16 CPU network, more than 250,000 ns2 nodes could be simulated.

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