EXCERPTS FROM THE MANET MAILING LIST ON LAYER INTERFACE AND MODELING ISSUES

Which Layer?

Date: Thu, 28 Aug 1997 22:25:28 -0400
To: Charles Perkins <cperkins@hsmpka.eng.sun.com>
From: Chip Elliott <celliott@bbn.com>
Subject: Which Layer?

>What does TTL mean anyway? Conventionally, it means number of hops. When subnetwork layers start distorting the meaning of TTL by tunneling or ATM-style methods, it seems to me that TTL becomes meaningless as a routing metric, or for that matter an end-to-end statistic.

Charlie,

Are you against Ethernet hubs and bridges? ;-)

But more seriously, I do agree that it's kind of thorny trying to decide, in general, whether an ad hoc network should be a single IP subnet or not. There are indeed arguments on both sides; and in fact, even having Ethernet bridges can make certain IP problems harder (eg integrated services).

Here is perhaps one way to approach it. Do we really want to build ad hoc nets out of multiple technologies, e.g., throw together a bunch of hosts using any mixture of radios, Ethernets, serial lines, etc. If the answer is a resounding yes, then we must use IP layer routing. If that is not our main focus, then we are probably talking a solution that works below IP.

Note that the "ad hoc nets built of mixed subnet technologies" is noticeably harder than the plain-old ad hoc net problem, since these different technologies have quite different characteristics (bandwidth, error, MTU, ...) which should somehow be reflected in the forwarding decisions. Just handling radios is hard enough, do we really want to add all this...!

Personally, I prefer the below-IP approach, and feel that efforts to standardize the "network formation and forwarding" parts of ad hoc nets should be an extension (rewrite) of the 802.11 spec. But there is certainly room to differ here.

Chip

MANET WG mtg minutes

M. Scott Corson (corson@Glue.umd.edu)
Tue, 9 Sep 1997 12:31:15 -0400 (EDT)

…Minutes of Mobile Ad Hoc Networks (manet) Working Group Meeting
Munich IETF, August 1997

…Agenda Item 1, Scott Corson

Presentation of draft entitled "Mobile Ad Hoc Networks: Routing Protocol Performance Issues and Evaluation Considerations" by M. Scott Corson and Joe Macker.

The draft gave a brief history of mobile packet radio, the relationship of this technology to other networking technologies in the context of hybrid communication networks, and a list of possible military and commercial applications. The draft then goes on to define a Mobile Ad hoc NETwork (MANET) as a set of mobile nodes (combined radios/routers) communicating with some form of wireless technology. The salient characteristics of MANETs are dynamic, randomly changing topologies, bandwidth-constrained links, potentially energy-constrained nodes (battery powered) and limited physical security (easy snooping).

There was discussion of how this definition compared with commercial ad hoc technology--in particular, IEEE 802.11 and HIPERLAN. It was mentioned that in its present form, 802.11 essentially considered only single-hop operation (no routing), and that the MANET definition was much closer to the latest version of HIPERLAN which permits multihop operation using a substantially modified form of link-state routing.

…Agenda Item 4, Dave Johnson

Dave presented "Dynamic Source Routing" (DSR), another demand-based routing protocol, but one which uses source routing as opposed to hop-by-hop routing. It consists of route discovery and route maintenance phases. Route maintenance is straightforward, and consists of passively monitoring the health of existing routes by listening to the ACKs of data packets transmitted to adjacent neighbors. The listening is either explicit through reception of a direct ACK, or implicit by monitoring adjacent neighbor's transmission activity while the receiver is in promiscuous mode. When a route is needed, route discovery is performed--a process which consists of a two or three-stage process. First, a source floods a query looking for the destination, or some intermediate node that has a path to the destination (as it travels, the query records the route it takes and grows in length). If neither is found, the source can query again later. If either is found (this node is generically referred to as the *replier*), a reply--carrying a full source route--is sent back towards the source. If the replier has a route to the source (this will always be true if one assumes unidirectional links), the reply is unicast; otherwise, it is piggybacked onto a query looking for the original source (the query is also recording the route back to the destination). When the source receives the route, it may begin sending data. If the reply was piggybacked, then the source also replies to the replier via unicast sending it the route by which the source may be reached. The protocol makes use of aggressive caching in that any node participating in the exchange may snoop on the routing information in the control packets to keep its cache up-to-date. Also, the protocol has no hello protocol (periodic link status messaging)--link health is monitored passively. It was mentioned that one way to view the protocol is as a multihop extension or generalization of ARP….

Agenda Item 5, Scott Corson

Resumed presentation of MANET issues draft...

…The question was also raised as to whether routing should be a layer 2 or layer 3 function? Numerous multihop wireless networks have implemented routing at the layer 2 subnet level with a mapping to IP only at the edges such as the NTDR network. The consensus of the working group was to implement routing as a layer 3 function. The MANET issues draft states that the rationale is much the same as the original Internet--to develop a homogeneous networking capability over a heterogeneous networking infrastructure. In this case, the infrastructure is wireless, rather than hardwired, with multiple platforms, radios and access technologies.

…The discussion on protocol evaluation moved to simulation, and to what level of detail would be necessary to have an accurate and realistic performance evaluation. There was much contention here within the group covering issues such as:

- how accurately to model a radio channel?
- need we consider terrain/environmental models?
- do we need to model a multiple access protocol in the simulation?
- does the choice of a multiple access protocol favor one mode over another?
- do we need to use a common simulation tool?
- what sorts of mobility models are appropriate? If Brownian motion is no good, what's any better?
- how does the choice of a mobility model affect relative protocol performance?
- etc.

The discussion was contentious and consensus was no where in sight when the discussion had to be curtailed due to time constraints. During the discussion, people continued to talk past each other due to the lack of a common frame of reference (a set of commonly accepted definitions for the terms being used in this context). Thus, the need for a *MANET lexicon* became apparent, and it was agreed to begin drafting one as an Informational RFC to aid group communication. What came out of the discussion was general agreement as to the need for a common simulation tool so that models can be shared and simulation results mutually verified. The two leading candidates are Maisie and NS as they are freely available. There was general agreement to take the discussion to the list….

Manet Minutes from 40th IETF

Joe Macker (macker@itd.nrl.navy.mil)
Tue, 23 Dec 1997 18:03:56 -0800

…Please note that any decisions will be set out by '***' and indentation.

… - What is the effect of lower levels? What if information is hidden from the upper layers? How much needs to be discussed regarding L2/L3 interface requirements?

***
To clear some of this up, it was suggested that applicability statements be included when and where appropriate. Statements should include notes on where the protocol works best, what scenarios it best applies to and any known limitations.
***

Modeling considerations for Ad Hoc Routing Protocols - Jay Strater: Mitre

The simulator used was OpNet with homebrew additions, and netlab.
Some channel access and routing protocols have been simulated.

Considerations:
- It would be great to simulate all the way down to the physical layer. But what do you really need?
- The army looks at a mix of traffic, addresses, service requirements, distribution of nodes, terrain, mobility factors.
- The physical and lower layer protocols are approximated.

Classes of traffic:
- Engagement ops: reliable, timely
- Command/control: reliable, slower
- Situational Awareness: time sensitive, not critical

Network addressing:
- Entire network of nodes: All nodes are sources and destinations.
- Lots of multicast applications.

Raleigh normal statistics are used. Node distributions, propagation losses and topology are drawn from 'terrain maps'. You can simplify this process by using node connectivity from statistics and propagation analysis.

How many nodes are up or down? Radio mobility was discussed -
- Noise and background interference is hard to simulate.
- Physical layer overhead - important to consider.
- Assume perfect acks.

Link layer:
- Framing overhead
- transmission overhead
- Military: Uses long preambles.

Evaluation framework: (factors evaluated for 300 and 1000 nodes, under 300 (platoon sized) are considered too small for the high-grade communication equipment.)

- traffic mixes, types - connectivity (dense/sparse)
- source and destination addressing - mobility factors
- loads - network sizes
- routing protocols

Notes on messages and transport in mobile nets:

- TCP doesn't work well. One needs a variant. Could this be NETBLT?
- Consider packet performance, not message performance.

By the end of the year, the project at MITRE will let folks have access to their model. They will apply their techniques to Garcia and Perkins algorithms. They will start work on layouts for terrains, using averages and histograms for their simulators.

Mix of voice, data with various distributions of range will also be included.

Administrative issues, wrap up - Joe Macker

…Should we allow or consider heterogeneous link layers? It was pointed out that this is a major goal of routing at the IP layer and should be preserved unless strong arguments are give to the contrary.

Design for what is realistic: We don't know where the technology is going in 2 years.

!!!
We need to decide what the design space is for link layer interfaces.
!!!

It was pointed out that discussion emphasis has so focused largely on potential radio routing technologies. What about IR? There are "non-radio" wireless technologies. This brought up the point again regarding whether the group should write about "channel access" and "specific link layers" in drafts? It was cautioned that this can lead into a "can of worms" but there was consensus that this warrants more exploration.

…With low power and short range, you need to use link layer information (which is specialized). Or do we create a 'family' of protocols which can rely on certain link layer facilities? Or do we work for a general protocol which doesn't use link layer information (which would be more expensive).

Other issues:

- Multipath routing, should we consider it?
- Support for multicast. Is this in or out of scope?

Re: NS mobility extensions?

Andrew T.Campbell (campbell@comet.columbia.edu)
Thu, 05 Mar 1998 19:06:15 -0800

…You are absolute correct: NS2 supports some MAC level functionality (viz. 802.11--) and rudimentary on/off channel models but no mobility support. We been adding some support for that but its too early to report any success….

> I'm currently preparing a simulation project on ad-hoc network routing for two master students. It seems like the NS environment is widely accepted by the MANET group to form the basis for routing protocol evaluations (or?).
> Anyway, we consider to use NS in our project since a number of studies on mobile/wireless systems have been conducted with NS and thus generated a number of "mobility extension" to NS that should be available. However, among these extensions I couldn't find any that actually models an environment of mobile hosts/routers moving around in and out of connectivity (due to radio range, radio shadows etc.) that should be very convenient to have when testing routing algorithms (the NS mobility extensions I found focused more on the wireless channel as such, with fading models for bit errors etc. Maybe I just missed what I'm looking for).
>
> Now, is anyone aware of such mobile environment extensions to NS?
> In any other simulation environment?
> Is anyone working on this kind of "package" ? (and willing to share ;-)
>

> Furthermore, relating to mobility environments with moving host. Has anyone any data on moving patterns of users/hosts that could be applicable here?
> I guess this depends *a lot* on the scenario (indoor local area , outdoor wide area, conferencing applications, vehicular applications,...)….
>

Issues...

M. Scott Corson (corson@glue.umd.edu)
Mon, 6 Apr 1998 11:50:36 -0400 (EDT)

…Summary:

1) IP Routing Fabric: The question was put to the group as to whether it was agreed that the principle reason for performing *IP-layer* routing in MANETs was to enable simultaneous usage of a multihop routing topology (or fabric) consisting of multiple physical-layer technologies. There was no disagreement.

2) Node Architectures: A generic MANET addressing scheme was put forth which adheres to existing IP practices by labeling interfaces with IP addresses and permits identification of MANET routers with identifiers termed "Router IDs". Along with this was presented the notion of two principle types of MANET routers: I) a host acting as a router and II) a pure router. Associated with the notion of a type-I *host-router* is the issue as to whether a host IP kernel's source code must be modified to enable MANET operation, or whether MANET operation can be realized via other mechanisms not requiring kernel source code modification.

…Transport/Network/MAC-Layer Interaction: Following on the heels of Mario's presentation of the effect of various MAC schemes on the performance of TCP, there was discussion regarding the extent to which TCP modifications should be suggested for better operation in MANETs, or whether MANET operation should be tailored to specific traffic types to provide better support for specific transport layer protocols and traffic classes. The general feeling was that modification of TCP was the choice of last resort, and that MANETs (and the gateways to them) should be tailored--to the extent possible--to support TCP and upper layer protocols in general. This might involve traffic-specific queueing and retransmission policies.

…3) Network/link interface

Presently, following IP practice, an interface can be identified simply by an IP address. This is a relatively *opaque* identifier, and does not permit network-layer differentiation of heterogeneous physical layer technologies (from their external interface) for purposes of routing; i.e. they all appear equivalent.
* How should this be enhanced or enriched (if at all)?
* How can this be utilized for routing in a way that co-exists with existing IP kernels, or are customized kernels a prerequisite here?

4) Upper layer/network layer interactions

Mario's presentation shed some experimental light on a fact that everyone probably knows already--without modification, TCP and other upper layer protocols may not work well in MANETs using contention-based MAC protocols (e.g. 802.11, Wavelan, Ricochet, etc.) unless appropriate measures are taken at the network layer and below to improve performance.

What network-layer measures might we wish to consider for use in MANETs? For example, what queuing practices should be adopted? Should these be traffic-specific? Again, how much is feasible using routers based on monolithic IP kernels?….

Re: Issues...

Dave Johnson (dbj@cs.cmu.edu)
Sun, 19 Apr 1998 00:53:46 -0400

>... NS2 has great upper level protocol support, and may now have a good wireless mobility/topology model depending on what Dave has developed. This makes usage of NS2 very promising as its missing ingredient--the network layer routing code--is what each protocol proponent can develop and distribute to the others.
>
>Dave: You mentioned in the meeting that this might be available by summer. Why not now? ;-) If you've done what the group requires, it would be great to get everyone using it ASAP.

…For those not at the MANET meeting in Los Angeles, our extensions to NS2 provide a detailed simulation of the physical and link layer behavior of a wireless network, and simulate movement of nodes within the network. At the physical layer, we provide a realistic simulation of factors such as free space and ground reflection propagation, propagation delay, transmission power, antenna gain, capture, and receiver sensitivity. At the link layer, we simulate the complete IEEE 802.11 wireless LAN DCF MAC protocol. The simulator allows programmable node mobility and communication patterns and operates on a terrain defined by a loadable digital elevation map.

Re: quantitative comparisons?

Vincent D. Park (vpark@itd.nrl.navy.mil)
Thu, 20 Aug 1998 09:53:17 -0400

>We will have a paper at MobiCom'98 (the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking) that does extensive performance comparison between our protocol (DSR) and 3 other ad hoc network routing protocols. The title of the paper is "A >Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols", by Josh Broch, David A. Maltz, David B. Johnson, Yih-Chun Hu, and Jorjeta Jetcheva. Here is the current abstract of the paper:
>
> ….We have extended the ns-2 network simulator to accurately model the MAC and physical-layer behavior of the IEEE 802.11 wireless LAN standard, including a realistic wireless transmission channel model, and present the results of simulations of networks of 50 mobile nodes.>

I noticed that you list TORA as one of the protocols in your comparison, but not IMEP. Did you also implement IMEP to provide link-status sensing (i.e., neighbor discovery), TORA control packet aggregation and ensure reliable in-order delivery of TORA control packets to the set of neighboring nodes? While the control packet aggregation provided by IMEP can viewed as an optimization (reducing the frequency of channel access), the link-status sensing and reliable in-order delivery of control packets provided by IMEP is *required* to ensure the correctness of TORA. As currently specified, TORA depends on IMEP to ensure these requirements are met.

Re: MANET Addressing Architecture

Fred L. Templin (templin@erg.sri.com)
Wed, 02 Sep 1998 10:57:37 -0700

…I was in attendance at the MANET WG meetings and was disappointed that time did not permit this discussion to continue, so I really appreciate your taking it back up again here. I'll insert a few comments/questions in your excerpted text below:

> A MANET node can loosely be thought of as a mobile entity in a MANET to which information is transmitted and received. Its composition and means of identification are the issue here. For this discussion, I will define a MANET "node" as an abstract entity consisting of a MANET "router" and set of affiliated mobile "hosts".

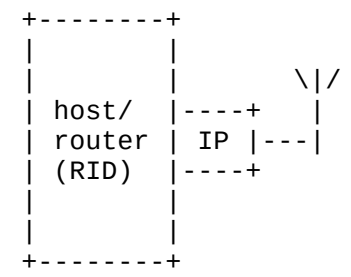
I think you need to define "affiliated" mobile hosts a bit more firmly. If by "affiliated", you mean that the hosts are somehow "tethered" to their corresponding router (either via hardwired links or wireless links which can somehow never be broken) then I can see the distinction of hosts vs routers. But, if the affiliated hosts are free to move; possibly losing touch with their router and coming into contact with other hosts and routers, then I think the concept breaks down. In this case, you would want such mobile hosts to behave like routers as well, in the sense that IMEP defines a router. That is, you

would want the mobile host to participate in the BEACON/ECHO process to discover its single-hop and multi-hopped neighbors as it moves.

> Policies and protocols for IP and RID assignment and management will likely be developed (perhaps in a separate working group), or on an as-needed basis within a given administrative domain. These policies should reflect the nature of a given MANET domain, just as a routing policy should reflect the nature of a domain. It is the view here that policies should be dynamic (varying from domain to domain), but core elements such as the addressing architecture must be uniform across the MANET space for interoperability within the space and with the fixed network. Otherwise, how do elements of the fixed network easily interoperate with stub MANETs if each has a separate addressing architecture?

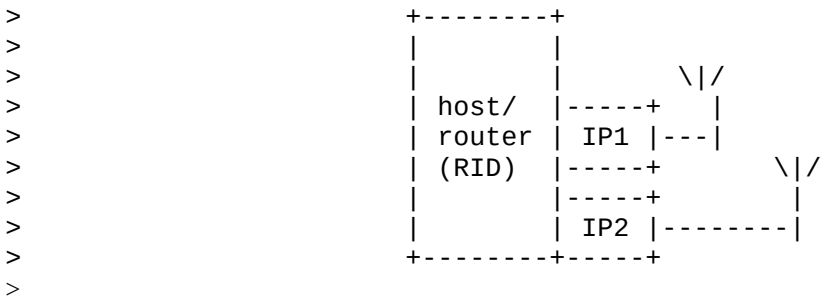
Without trying to debate between the AODV vs. DSR vs. IMEP approaches, I think the RID assignment can be done rather easily. Why not just pick one of the router's interface identifiers (IP addresses), designate it as the "primary address" for this router, and set the RID to that address?
Even if the router moves and its interface identifiers change, I think you are still OK to just set the RID once and for all. In a way, it would be like the Mobile IP concept of a "home address".

> Analysis of some Special Cases:
>
> 1) A mobile host may be coincident with a MANET router (i.e. the *same* device) with only a single wireless interface.
>



>From what I've seen in the GloMo, SUO, and Tactical Internet scenarios, I believe this will actually be the more general case for mobile hosts. That is, the mobile host will have a single radio with no pre-configured notion of the network topology, and so it will need to adhere to some channel access protocol (like 802.11) and also go about discovering its network neighborhood through some means such as IMEP. It should also participate in multi-hop packet forwarding (notice I didn't say "routing") in cases where it can serve as the go-between for other hosts, and so it begins to look like a single interface router in the spirit of IMEP.

> 2) A mobile host may be coincident with a MANET router (i.e. the *same* device) > with multiple wireless interfaces.
>



> In this case, the host is multi-homed, and inherits the identities of the router's IP addresses. Here, the RID is clearly necessary, as it > permits routing through a multi-technology multihop wireless fabric. Here, the tuple (RID,IP1,IP2) needs advertisement for full routing capability.

Again from the GloMo, SUO, Tactical Internet experiences, I believe this configuration will be common, but not as widespread as the single-interface case. It should also be considered that the interfaces may be a heterogeneous mix of both wired and wireless devices. Then, within the subset of wireless interfaces, this sort of configuration should behave like a multiple-interface router in the IMEP sense, and within the superset of all interfaces it should behave as a traditional router in the classical Internet sense….

Hidden Terminals (Addressing, Unidirectional links)

Chip Elliott (celliott@bbn.com)
Tue, 08 Sep 1998 17:15:24 -0400

The link layer has a fairly important vote in exactly what kinds of links are supported, and whether or not nodes have link-level addresses.

It seems to me that the earliest packet radio networks had some pretty bad performance problems due to the "Hidden Terminal" problem, which is in simplified form:

A is in range of B, which is in range of C, but A and C cannot hear each other. Now packets from A and C to B will step on each other, so B will have poor performance.

Today's usual solution to the Hidden Terminal problem is a MACA-like waveform, ie, a 4-way handshake involving an RTS (request to send), CTS (clear to send), data frame, and frame ACK.

This waveform imposes constraints on the upper layers:

1. It only works on bidirectional links.
2. It requires the upper layers to have netwide unique MAC addresses.
3. It does not support broadcast or multicast.

Point 3 is especially important: those systems that RELY on all nodes broadcasting (for normal packet forwarding, eg) WILL suffer from the Hidden Terminal problem.

Thus it seems we have a basic choice:

a) Use a unicast MACA style system at the link level, eg, 802.11 b) or broadcast and suffer from the Hidden Terminal problem

Note that one can use modern 802.11 radios with either the MACA waveform (unicast), or broadcast, so our networks could take either of these choices -- or a judicious mix of both features, such as using broadcasts for beacons and routing updates, but unicast for message forwarding.

Re: Hidden Terminals (Addressing, Unidirectional links)

Jose Garcia-Luna (jj@cse.ucsc.edu)
Tue, 08 Sep 1998 15:37:48 -0700

…I quite agree with your note, except that I'd encourgae MANET people to look beyond 802.11 and address MAC-level protocols that support multicast transmissions, to think about what it means to have unidirectional links at the MAC layer, and to exploit the neighbor information provided at the MAC layer.

Unless that is done, talking about a routing protocol sending fewer HELLOs than another protocol or talking about a routing protocol operating with unidirectional links is only interesting as an academic exercise, because in practice HELLOs should not be needed (in most cases) and---if we want to remedy h-t problems to some degree--we only have bi-directional links with p-t-p MAC protocols commercially available today. I do not think we can live with the commercial solution to broadcast, which is ALOHA (carrier sensing does not work with h.t. and there is no true carrier sensing in commercial radios).....I think once we stare at the problem long enough, we'll end up with a MAC protocol that resembles TDMA in some ways.

As for all these references to "MACA" I keep hearing, I'd like to give due credit to Kleinrock and Tobagi, who were the first to propose the "RTS-CTS" like handshake. The protocol was called SRMA (part III of the pkt switching in radio channels papers, Trans Comm, 78, Vol 24, No 8, pp 832-845, or read Tobagi's ucla thesis). MACA amounts to a single-channel SRMA using ALOHA to send RTSs.

Re: Hidden Terminals (Addressing, Unidirectional links)

M. Scott Corson (corson@glue.umd.edu)
Wed, 9 Sep 1998 14:10:37 -0400 (EDT)

> > Hopefully...protocols like this will soon become available...at present, the WG is stuck with what it can buy.
>
> In the wired world, there are lots of RFC's that tell how to run IP atop various data link protocols (e.g. RFC 1042: Standard for the transmission of IP datagrams over IEEE 802 networks). Perhaps there is a need for something along these lines for MANET, e.g. "The operation of MANETs over IEEE 802.11 networks". It's great to have all of this routing work going on, but at some point you need to look at how the "rubber meets the road".

Sure...but for this sort of thing to occur, we first need to agree on standardized approach for the MANET stuff, otherwise there is nothing for the link-layer stuff to interface with...that's one reason I'm suggesting we come to a common understanding regarding basic issues such as host and router identification in MANETs.

Re: Hidden Terminals (Addressing, Unidirectional links)

Joe Macker (macker@itd.nrl.navy.mil)
Wed, 09 Sep 1998 14:46:29 -0400

…Yes, at a certain level of maturity such documents should occur. It can help to agree first at a higher layer on the level of flexible functionality to be provided by a routing layer interface.... then specific link layer issues can be worked on overtime. If the initial interface framework defined is flexible (somewhat technology independent) this can be less painful than otherwise, but there certainly is some interplay between what is decided there and what goes on across different link layers.

There is additional historical IETF precedence for your suggestion. Consider the intserv, rsvp, and issll WGs and their relationships. In this case, different WGs took on different responsibility roles and problem focus while working closely together. ISSLL focuses on specific link layer interface and functional mapping issues. Much of ISSLL's work required a certain amount of maturity in upper layer specifications (i.e., rsvp and intserv).

Re: Hidden Terminals (Addressing, Unidirectional links)

Ram Ramanathan (ramanath@bbn.com)
Wed, 09 Sep 1998 15:26:23 -0400

…This discussion reminds me of the light-bulb joke : "How many software engineers does it take to change a light bulb"? Answer "None, it is a hardware problem".

More seriously though, the more I work in this field, the more I feel that the layering approach that was so useful in the wired world may not really fly in the mobile wireless world (I mean in practice, everything works on paper). While the main villain is the channel access, there is so much need to pass information across layers (punch holes in the layers) that the stack soon looks more like a honeycomb. JJ mentioned the acquisition of neighbor information using the MAC layer itself. And I might want to control my local neighborhood by adjusting xmit power...

Different routing protocols may work best with different MAC layers. One approach, as you say, is choose one solution at the network layer and then worry about which MAC layer suits it best. However, if am not interested in standards or layering or IETF and simply want to get the best possible mobile wireless system, I would rather choose the best routing-channel access *combination*.

As part of GloMo Multimedia Support for Mobile Wireless Networks (MMWN), we did some work on routing algorithms at the network layer, and hoped that the "right MAC layer would come along by the time we are done and we would be all set" (similar to MANET?). Well, all we needed was a MAC layer that does efficient multicast, provides reserved access for QoS support, is simple, doesn't have too much overhead, tolerates hidden terminals and works with unidirectional links! We are still waiting. For the hardware engineer to fix the light bulb. Any takers? :)

Re: Hidden Terminals (Addressing, Unidirectional links)

M. Scott Corson (corson@glue.umd.edu)
Wed, 9 Sep 1998 19:13:32 -0400 (EDT)

As I understand it, the data link address has no network-level significance.

ARP determines a temporary binding between an IP address (network-level significant) and a link-level identifier for purposes of link-level reception filtering on a given subnet. IPv4 mixes the notions of network-level identity and location by encoding both in the same number, a host's home address. Mobile IP is one approach for distinguishing between them where, in one mode, a node's network-level *identity* becomes its home address (while on the road) and its *location* in the network is its care-of address.

> You might be able to statically assign an arbitrary-length IPv4 network prefix (e.g. 128.129.130/24) as a router's ID, but then you really can't allow simple hosts to dynamically associate/disassociate with the router (due to mobility) unless the router has some way to dynamically allocate them addresses out of the 128.129.130/24 address space. I believe this brings us back to the need for a way to uniquely differentiate nodes; whether it be through 802-style datalink addresses or some other way that hasn't been mentioned yet. Otherwise, how could dynamic IP address allocation be managed? In short, I don't think it's possible to consider the MANET addressing in isolation from the underling datalink/physical levels without spelling out the assumptions being made.
>
Interoperability with link-layers such as 802.11 may entail certain functionality, including some form of ARP-like link identifier exchange between nodes that bump into one another. This would be part of an interface spec that needs to be written for a given link layer.

As Joe indicated earlier, specs are commonly written for the network-layer to interoperate with certain link layers. Such a spec would be useful for 802.11, enabling various network-layer protocols (such as IMEP) to glean useful information from a given link layer, thereby allowing them to reduce or eliminate unnecessary signaling overhead over their 802.11 interfaces. The network-level assumptions and connection signaling mechanisms currently spec'ed in IMEP are necessary to enable operation over a generic link layer from which no such information can be obtained (such link layers commonly employing some form of CSMA/CA exist today). IMEP is modular, and is intended to be modified to operate efficiency on

interfaces for which such link-layer-specific information is available. I encourage anyone interested to submit an MANET/802.11 interface spec draft.

Still (taking the datalink identifiers out of the picture), the issue of network-layer identification of hosts and routers is very important. My comment last week suggested a way to *structure* the identification process, but did not specify *how* to assign the identifiers. That is policy-specific, and is an active research topic.

Flooding & Hidden Terminal?

Chip Elliott (celliott@bbn.com)
Mon, 14 Sep 1998 12:28:47 -0400

I've been thinking about flooding schemes and the hidden terminal problem, and hope that someone (CMU?) can enlighten me.

Imagine a large network using flooding as part of its path-building activities. I expect that flooding would be accomplished via radio level broadcasts; to be concrete, let's say 802.11 broadcasts.

Now it seems to me that such floods would suffer quite a bit from hidden terminal problems, since the transmissions would be highly synchronized -- a number of nodes will be transmitting at virtually the same time -- and broadcasts are not protected from hidden terminal problems. Hence it seems conceivable that the actual completion rate on these flood searches might be quite low... i.e., a large fraction of the requests will be damaged in transmission and hence have no effect.

CMU folks, have you noticed any such effects in your simulations? If not, why not -- ie, what part of my thought experiments are wrong?

Re: Flooding & Hidden Terminal?

M. Scott Corson (corson@glue.umd.edu)
Sat, 19 Sep 1998 16:26:37 -0400 (EDT)

…I guess I'm echoing some of Joe's thoughts, but it seems that any heavily loaded network (read "congested" as some envisioned MANETs will be) will suffer from HT problems using 802.11. The "problem" is less with flooding (it's simply a network-level traffic pattern) and more with less-than-ideal MAC layers and slow radios. Flooding is expensive and should be used sparingly, but it has legitimate uses.

In the near term, it may be that flooding is the only way to create congestion in some otherwise lightly-loaded networks, thereby exposing otherwise hidden weaknesses of the link layer. If the far term, as MAC and radio technology improve (this will happen...right ;-), flooding will become less of an issue, simply contributing a fraction of the overall network load.

Question: Has anyone simulated a fully-loaded 802.11 multihop network to measure performance in terms of supporting one-hop unicast and broadcast reliability? JJ...have you done so with FAMA, and cross-compared with 802.11 under fully-loaded conditions?

Re: MAC LAYER DESIGN

Ram Ramanathan (ramanath@bbn.com)
Fri, 20 Nov 1998 12:57:14 -0500

…Most of BBN's ad hoc networking as a group has been in the network layer. I personally have done some fairly theoretical work on channel assignment modeled as constrained graph coloring. Perhaps this is what C-K meant. My most recent paper on this was in Infocom 97 titled "A Unified Framework and Algorithm for Channel Assignment in Wireless Networks" and can be found under the "related publications" link in http://www.net-tech.bbn.com/dawn/dawn-index.html. (This URL also describes BBN's network layer activities under the GloMo program for those interested.).

This paper, however, is not relevant to the original query that started this thread. None of the responses have really answered that question to my best knowledge. The question was

>I am working on mac layer design for adhhoc networks.

Have fun.

>I want to know which is the best suitable mac protocol

It is like asking: which is the best movie ever made :) everybody has their favorite MAC protocol (especially the people who invent one :) and a lot depends on the requirements.

>and what are the criteria on which you evaluate mac layer

Again, depends on requirements and constraints. Do you want to support bursty traffic or not? Do you have a large percentage of unidirectional links? Do you want to do multicasting? Do you want to give access delay guarantees? Capacity guarantees? On-demand access?

Once you define the problem for which you want the MAC protocol for, then you can talk about criteria. These could range from obvious ones like fairness and freedom from deadlock, to more sophisticated ones like minimal energy or interference mitigation.

I haven't seen work address this. None of the cited work look at "requirments" or "criteria" for MAC like Scott Corson and co have done for MANET routing. I think Fred Templin's idea of starting from the IEEE 802.11 is a good one.

While we are talking about existing ad hoc MAC work, I have seen some good work by defense contractors like ITT Aerospace, Rockwell Collins etc. Unfortunately, these guys rarely publish except in Milcom.

MAC is supposed to be out of scope for this working group, so let me stop before I get called for wasting bandwidth.

Re: MAC LAYER DESIGN

M. Scott Corson (corson@glue.umd.edu)
Fri, 20 Nov 1998 13:39:37 -0500 (EST)

I don't think you're wasting BW... ;-)

I think the protocol designers in this group have to be very cognizant of the link/physical layers over which they intend to run their protocols. One of the major issues (little addressed so far here as a group) is the interface to the link layer from network layer. Each link layer is somewhat different, and an adaptation layer between the network and link layer is required for each link layer (such as 802.11) to implement standard services for the network layer....initially, this service set may be fairly small (e.g. 1-hop unicast, multicast, or broadcast with or without reliability) over contention-based link layers like 802.11. But, as technology evolves, and more capable link layers are developed that support, for example, forms of reservation-based access, this service set may grow richer over time. An adaptation layer supporting this service set, which sits between the device driver and the network layer, can be developed for each new link layer. Alternatively, if the driver writers themselves seek to conform to some standard (something akin to the GloMo Radio API), then the network layer folks can simply write to this standard. A portion of this WG's charter is to consider the interface to the link layer, so this is a relevant discussion.

Re: MAC LAYER for MANET

Chai Keong Toh (Chai.Toh@ee.gatech.edu)
Fri, 20 Nov 1998 23:42:10 -0500 (EST)

…About the issue of MAC, I think it is important for routing protocol designers to understand the underlying channel access method and physical transport. I think it is impossible to support QoS by merely looking at a specific protocol layer only. This reminds me of the liaison established between the Wireless ATM Working Group at the ATM Forum and the ETSI BRAN group, which is concentrating more on the radio and MAC issues.

Based on what Scott had said in his last e-mail, I think it is good if IETF MANET group could establish a link with IEEE 802.11 or ETSI HIPERLAN group. The European HIPERLAN group works on MAC issues for High Performance LAN which includes both centralized access control and fully distributed access control….

RE: OPNET simulation model for ad-hoc network

Chip Elliott (celliott@bbn.com)
Fri, 04 Dec 1998 10:15:11 -0500

…We run our models in two different ways: with a "quick and dirty" MAC layer that has very little realism, and in a highly realistic mode that does a very thorough job of emulating our radios and their propagation, contention, etc. We're using special military radios which are quite fancy. In spirit, however, they are roughly like 802.11 for channel access, etc.

I'd definitely recommend the 802.11 MAC for your model. If you can do it, you should also try to make a decent propagation model. r**2 or r**4 don't really cut it, and you'll get exceedingly wrong results (in our experience).

Alas, we cannot share our models, as they are for military radios. You might have better luck with the MITRE model. Although OPNET has something of a bad reputation, I think it's actually a very good modeling environment. The license fees are really the main problem, IMHO.

The major problem with setup are the usual ones for modeling, I think -- to properly segment the model so that one can swap in "quick and dirty" components instead of realistic ones. Compute time is always an issue, and you need careful design up front so you can tailor your model's components to the task at hand.

RE: MAC protocols

Miguel Sanchez (misan@ieee.org)
Tue, 12 Jan 1999 21:36:49 -0000

…MAC at wireless networks has several particularities from general MAC algorithms. When you use a wired network, carrier sensing can be all right but can be impossible in wireless networks (see capture effect in radio networks). Because most wireless is broadcast by nature but propagation laws are different than in a wired media, some of the basis for wired networks do not apply to wireless ones. Several MAC algorithms have been proposed with this differences in mind:

o You could see Dr. Zygmunt Haas paper on Double Busy Tone MAC algorithm.
o You also can see 802.11 MAC specification.
o Another MAC algorithm taking into account has been published in ACM's Computer Communication Review Volume 28 Number 3 July 1998 "PAMAS – Power Aware Multi-Access Protocol with Signaling for Ad-hoc Networks" (by S. Singh and C.S. Raghavendra).
o MACAW protocol is described on ACM SIGCOMM'94 Proceedings p.212-225
o P. Harn MACA protocol

You also may be interested on reading about hidden terminal and exposed terminal problems….

link layer feedback

Kevin Purser (erakepu@etxb.ericsson.se)
Thu, 05 Aug 1999 10:35:34 +0200

…I am attempting to augment an existing AODV implementation with the Lucent IEEE 802.11 cards to utilize link-layer feedback (to detect broken links and such), and at present, I'm completely unaware where to find information on this topic. I would greatly appreciate if someone could point me in the right direction to find out how to obtain such feedback from the driver (or perhaps more needs to be done?).

Re: data slides on power consumption - Oslo meeting

Laura Feeney (lmfeeney@sics.se)
Thu, 5 Aug 1999 15:31:34 +0200

…Yes, I used the AODV-ll from the CMU release. I only added tracing to CMU ns2; the protocols didn't change at all.

Using hello messages in addition to link-layer failure discovery would definitely affect the energy consumption results. (Except perhaps in the case of a MAC layer which provides neighbor discovery.)

The CMU folks found that AODV hello messages hurt performance and so implemented AODV-ll (Mobicom'98 paper). But in Minneapolis, I recall that SwitchLab reported good results using hello messages. So perhaps there is some other difference between the two implementations. (Or perhaps my understanding is incomplete.)

Re: data slides on power consumption - Oslo meeting

Elizabeth Royer (Elizabeth.Royer@eng.sun.com)
Thu, 5 Aug 1999 13:04:40 -0700 (PDT)

…~> >> From my recollection there were 3 AODV versions implemented.
~> Joe> - hello only
~> Joe> - hello + Mac layer notification
~> Joe> - Mac layer notification only
~>
~> Yes, I believe it was the combination that yielded good results for Switchlab. In the 802.11 context, "hello only" doesn't make too much sense to me - you're just throwing away useful MAC layer information. (You want to avoid repeatedly deleting and rediscovering a marginal link, though.)
~>

If there is a MAC layer protocol being used, then AODV does not require the use of Hello messages. Hello messages are included so that we can have connectivity information and keep our routes up-to-date when there is no underlying MAC protocol.

>The current version of the AODV draft (03) specifies a limited TTL expanding ring search for route requests. Samir Das has been working with us and found that to be extremely helpful in limiting the impact of route discovery. Basically, we specify 3 values, TTL_START, TTL_INCREMENT, and TTL_THRESHOLD, which are used for the expanding ring search. We also specify that if a route to a destination is lost, then the initial ttl for the RREQ to rediscover that route should be the last known hop count to that destination + TTL_THRESHOLD. Please see Section 6.3.1 in our latest draft for more details.
>
oops - typo. That last TTL_THRESHOLD should actually be TTL_INCREMENT.

Research at the MAC layer

Padmanabhan Arvind (elepa@leonis.nus.edu.sg)
Fri, 24 Sep 1999 15:32:58 +0800

…I am currently doing research for ad hoc networking at the MAC layer and I am sure some of you at MANET have done research in this area. I would be glad if some of you can guide me on what has been done thus far at the MAC layer.

Most (if not all) of the stuff I see at MANET are on routing issues. I would like to find out if people have done studies at the MAC layer since efficiency at the MAC layer is be an important issue before we look at routing. Although routing schemes may be independent of MAC protocols it is the MAC protocol that determines how efficiently valuable bandwidth is used. This is especially relevant in an ad hoc network since packet collisions are possible due to the distributed nature of any protocol in such a network.

Some known MAC protocols for ad hoc networks are MACA, MACAW, FAMA, and DBTMA. IEEE 802.11 is also a possible protocol.

I am aware of the following works at the MAC layer:

1 Vaduvar Bharghavan, et. al., "MACAW: A Media Access Protocol for Wireless LAN's," Department of Electrical Engineering and Computer Science, University of California at Berkeley.

2 Jing Deng and Zygmunt J. Haas, "Dual Busy Tone Multiple Access (DBTMA): A New Medium Access Control for Packet Radio Networks," IEEE ICUPC'98, Florence, Italy, October 5-9, 1998

3 C.L. Fullmer, J.J. Garcia-Luna-Aceves, "Floor Acquisition Multiple Access for Packet Radio Networks," in SIGCOMM'95, pp. 262-273, ACM, 1995.

Re: Research at the MAC layer

jacquet@menetou.inria.fr
Fri, 24 Sep 1999 13:43:46 +0200

There is also the HIPERLAN type 1 MAC layer which includes ad-hoc routing. We have some implementations in INRIA.

Re: Research at the MAC layer

Chip Elliott (celliott@bbn.com)
Fri, 24 Sep 1999 08:55:08 -0400

…There has been a great deal of research in the MAC layer, dating from 1970 if not before. The packet radio work in the 70s and especially in the 80s gave rise to a number of schemes. Here are some papers that I like:

Norm Abramson, "The ALOHA System". Proc. Fall Joint Computer Conf, AFIPS, 1970.

A. Alwan et al, (Gerla & Kleinrock at UCLA): "Adaptive Multimedia Networks", my database doesn't say where it was published, 1996.

Digital Ocean patent, "Medium access control protocol for wireless network", 1993.

Robert Gallagher, "A Perspective on multiaccess channels", IEEE Trans on Information Theory, March 1985.

Mario Gerla and J. Tsai, "Multicluster, mobile, multimedia radio network", my database doesn't say where published, 1995.

IEEE, Special Issue on Packet Radio Networks, Proc IEEE, January 1987.

Kahn et al, "Advances in packet radio technology", Proc IEEE, Nov 1978.

Clifford Lynch and E. Brownrigg, Packet Radio Networks. Pergamon Press, 1987.

Metricom patent, "Automatic power level control of a packet communication link", 1993.

Metricom patent, "Method for frequency sharing and frequency punchout in frequency hopping communications net", 1994.

Robert Morrow and J. Lehnert, "Packet throughput in slotted ALOHA DS/SSMA radio systems with random signature sequences". IEEE Trans Comm, July 1992.

Elvino Sousa and J. Silvester, "Spreading code protocols for distributed spread-spectrum packet radio networks", IEEE Trans Comm, Mar 1988.

J. Storey and Fouad Tobagi, "Throughput performance of an unslotted direct-sequence SSMA packet radio network". IEEE Trans Comm, August 1989.

H. Takagi and Kleinrock, "Optimal transmission ranges for randomly distributed packet radio terminals", IEEE Trans Comm, March 1984.

Greg Troxel, "Time surveying: clock synchronization over packet networks", Tech Report MIT/LCS/TR-623, Lab for Computer Science, MIT, May 1994.

I think I remember a paper by Tobagi and Kleinrock, or multiple papers, from the late 70s that introduce the idea of RTS/CTS to fight the hidden terminal problem.

Also two theses that I find particularly good, both about 4-5 years old:

S. Ramanathan, U. Delaware, I recall its work on computing TDMA schedules.

T. Shepherd, MIT, Dencentralized Channel Management in Scalable Multihop Spread-Spectrum Packet Radio Networks. (1995)

Finally you should also check various commercial standards such as 802.11 which has not one but two well-developed MAC schemes, CDPD, and the GSM packet data mode.

Re: Research at the MAC layer

Jose Garcia-Luna (jj@cse.ucsc.edu)
Fri, 24 Sep 1999 07:58:09 PDT

…pls go to:

http://www.cse.ucsc.edu/research/ccrg/publications.html

There is a section on MAC papers there from my group....and more routing :)

Re: Research at the MAC layer

Ram Ramanathan (ramanath@bbn.com)
Fri, 24 Sep 1999 10:50:18 -0400

…Another "perspective" paper, especially for people new to the area is

F. Tobagi, "Multiaccess Protocols in Packet Communication Systems", IEEE Transactions on Comm, April 1980

It surveys the various channel access approaches in a fundamental manner for all kinds of networks including ad hoc (they used the term "multihop radio" then).

For TDMA schemes, you may want to check out the following paper for the bibliography, the paper itself is probably too theoretical....

S. Ramanathan, "A Unified Framework and Algorithm for Channel Assignment in Multihop Wireless Networks", Wireless Networks 5 (1999) 81-94.

There is also good work by the military contractors like ITT Aerospace, Hughes, Rockwell Collins, Raytheon etc. but these guys don't publish much ;-) But the IEEE Milcom conference typically has some papers by them.

Finally, while you'd probably have lots more fun working at the MAC layer than the network layer, I am not sure that the MANET working group is the right forum for it. I think there was a discussion on this a year or so ago and people said something like "we ought to be aware of effects of MAC layer, but MAC research is out of scope". But I could be completely wrong, so you ought to check out the charter/archives or talk to the chair.

Re: Research at the MAC layer

Y. C. Tay (mattyc@leonis.nus.edu.sg)
Sat, 25 Sep 1999 03:02:54 +0800 (SST)

I was just informed by the editor at Wireless Networks that this would be accepted:

http://www.math.nus.edu.sg/~mattyc/802.ps

Re: Research at the MAC layer

Ajay Gummalla (ajay@cc.gatech.edu)
Sat, 25 Sep 1999 08:50:48 -0400

…You could also take a look at this review paper i had written. It discusses the issues in the design of wireless MAC protocols in general and compares different design choices.

http://www.cc.gatech.edu/~ajay/survey.ps.gz

Feasibility of busy tones

Ken Tang (khtang@ucla.edu)
Mon, 25 Oct 1999 17:52:22 -0700

…I was wondering if any of you know anything about the feasibility of using busy tones as described in Tobagi/Kleinrock [1] and Haas [2] in real implementations or is busy tones primarily an academic/research
interest?

[1]. Fouad A. Tobagi and Leonard Kleinrock, “Packet Switching in Radio Channels: Part II – The Hidden Terminal Problem in Carrier Sense Multiple Access and the Busy Tone Solution”, IEEE Trans. Comm, COM-23, 1975.

[2]. Jing Deng and Zygmunt J. Haas, “Dual Busy Tone Multiple Access (DBTMA): A New Medium Access Control for Packet Radio Networks,” IEEE ICUPC’98, Florence, Italy, October 5-9, 1998.

AODV implementation

Kevin Purser (Kevin.Purser@era-t.ericsson.se)
Thu, 04 Nov 1999 11:16:53 +0100

…As we have received numerous mails recently regarding our AODV implementation, here's a summary of what we are presently doing, and the problems we've run into to date.

My responsibility involves incorporating internet access into ad hoc networks through the use of Mobile IP (for dataflow into the ad hoc net) and modifications of AODV (for gateway support for the opposite direction of dataflow).

Additionally, we have attempted to include link-layer feedback to allow quicker detection of broken links. We have been using using drivers for the Lucent WaveLAN 802.11 PCMCIA cards with drivers from both TriplePoint, Inc. and Andy Neuhaus. Neither have offered any assistance in the way of achieving such feedback from their drivers, so this aim has been postponed.

In order to to use Mobile IP for ad hoc networks, a few modifications have been made. First and foremost, since the connection between a FA and a node within an ad hoc network may traverse multiple hops, we've moved Mobile IP from the link-layer into the IP layer to allow the connection to be fulfilled through IP forwarding. There are a number of other questions as to how to resolve the differences in MIP and the on demand behavior of AODV, which are under investigation. Some examples:

* Should a FA continue broadcasting it's periodic advertisements throughout the ad hoc network, should they be restricted in some way, or simply be removed entirely?

* If multiple FAs can be reached by nodes in an ad hoc network, which is the "best" to use, and how to we acquire this metric?

* If a path to a node's currently registered FA is broken, should it try to re-establish a path to that FA, or immediately try to discover a new one?

Regarding the opposite direction of dataflow, supporting multiple gateways also poses problems:

* If a node requests a route to a destination which may reside on the internet (or within the ad hoc network using mobility mechanisms), how should gateways respond to such requests?

* If multiple gateways can be reached by nodes in an ad hoc network, which is the "best" to use, and how to we acquire this metric (a less specific version of the problem involving multiple FAs)?

These are all under investigation through simulation, and a canonical implementation is also underway. The results of these works will be published during the coming months.

Re: [Fwd: AODV implementation]

Bill Paul (wpaul@ctr.columbia.edu)
Thu, 4 Nov 1999 13:56:44 -0500 (EST)

> Additionally, we have attempted to include link-layer feedback to allow quicker detection of broken links. We have been using using drivers for the Lucent WaveLAN 802.11 PCMCIA cards with drivers from both TriplePoint, Inc. and Andy Neuhaus. Neither have offered any assistance in the way of achieving such feedback from their drivers, so this aim has been postponed.

Regards the drivers and radio interaction:

Note that it is not particularly easy to do this with the WaveLAN/IEEE cards when operating in "ad-hoc" mode. As I've mentioned in the past, Lucent doesn't actually implement IBSS mode in the same manner as the Aironet cards: they actually implement pseudo-IBSS mode, which operates without any explicit association between stations. Basically, as soon as you activate the card, you are "connected" to the network. If another station happens to be within radio range, you will be able

to communicate with it (ping it, open TCP connections, etc...). If that station moves out of range, you won't get any special indication from the NIC: the only thing you'll notice is that packets from the other station have stopped coming. An additional side effect of this behavior is that it's impossible to group ad-hoc stations into separate cells at the link layer: all WaveLAN/IEEE stations operating in ad-hoc mode implicitly end up in the same ad-hoc network and will hear each other's traffic as long as they're within radio range.

My understanding is that Lucent wants to implement proper IBSS mode in their firmware, however I don't know what their schedule is.

With real IBSS mode, ad-hoc stations form a private service set with one station being the "master" station. Once associated, you can inspect the BSSID stored in the NIC; this value is unique to the service set, and is chosen randomly by the master station when it's first activated. If you move out of range of the service set, this BSSID value will change (it will become all zeros, or possibly some other "empty" value). This mechanism is also used in BSS mode with an access point, only in that case the BSSID is the MAC address of the access point instead of some random value. (Note that this applies to the WaveLAN/IEEE cards as well: when a WaveLAN/IEEE card is associated with an access point, the BSSID will indicate the access point's MAC address. When not associated, the
BSSID contains some bogus value -- if I recally correctly, I think it contains 44:44:44:44:44:44.)

The Aironet NICs maintain the association with the "master" ad-hoc station by exchanging beacons. When you see the green LED flickering even when the host isn't sending any data, those are the beacons being exchanged. The beaconing interval can be adjusted: the slower you make it, the more time it will take for the NIC to decide that it has become disassociated from the ad-hoc service set.

With the WaveLAN/IEEE cards, the BSSID has no meaning in "ad-hoc" mode: it's always an "empty" value whether you're in range of other ad-hoc stations or not. The only thing you can do to detect "broken links" is to monitor the signal strength when receiving packets. The host software has to decide when the signal has degraded enough to consider the connection between stations to be broken.

Both of the Linux drivers mentioned here use the Lucent HCF library for communication with the NIC (the TriplePoint one uses the commercial, proprietary version while the other uses the freely available HCF Light
version). I'm reasonably sure there's a way to extract the signal strength field from the received frame header. In my driver, you can get it by just reading the wi_q_info field from the wi_frame structure.

The source code for aironet/WaveLAN/IEEE cards drivers can be found at:

http://comet.columbia.edu/cellularip/device/main_code.html

We are using these drivers in two projects in the COMET Group:

1) Cellular IP (we will release the source code next week) see: http://comet.columbia.edu/cellularip

2) INSIGNIA see: http://comet.columbia.edu/insignia/

Re: Ad-Hoc Simulation Model Questions

Joe Macker (macker@itd.nrl.navy.mil)
Wed, 10 Nov 1999 20:28:59 -0500

…There are certainly commercial omnidirectional systems that allow long ranges (e.g., Metricom, Nova) for sensible reasons (miles,etc often sacrificing throughput for improved range operation) and those designed to operate at shorter ranges for sensible reasons (e.g., Bluetooth). Wireless LAN technology range designs tend to be in between (when used without directional antennas). Plenty of good books with propagation models for link budget analysis but there are several degrees of freedom and a spectrum of choices..no pun intended.

> >> (1) What range of radio transmission ranges (distance) would be realistic and representative of what is available today or might be expected to be available in the near future? Assume a free-space propagation model.

> >
> >For WaveLAN radios, the power range for 2Mbps is 365m for an open environment and 167m for a semi-open environment. For 1Mbps, it's 425m and 198m, respectively.
> >
> We recently had a couple thesis students see just how far they could go > with 802.11 stuff. The numbers quoted above depend on some assumptions that one can change.
>
> The colorful version is that the students put AP on the roof of a building, plugged it into the campus LAN, attached a higher gain antenna, then took the other end out to a flying club airplane ... they were snapping pictures of the whales in Monterey Bay and e-mailing them back to the admiral. The airborne kit included stock Wavelen cards and a directional yagi antenna that one of the students hand pointed back in the general direction of the school. They were predictably and reliably getting 15-20 miles range. [!!] They did not fool with the speeds so all this was running at 2Mbps.

Re: Ad-Hoc Simulation Model Questions

Miguel Sanchez (misan@disca.upv.es)
Wed, 10 Nov 1999 09:59:51 +0100

…As other people is posting, a typical value ranges around several hundred meters outdoor. However, there is a strong relationship between the transmission range and the MAC layer behavior (i.e., a longer transmission range means a higher number of neighbors contending for the channel, therefore, MAC throughput will decrease or at least the available bandwidth for each node will be lower).

So, even if your transceiver is able to reach a long distance, you can obtain a better MAC-layer throughput by *lowering* the transmission range adaptively. (Please note too that this not necessary mean higher network layer throughput!).

Some information about the relationship between mobility models and transmission range can be found in http://www.ee.surrey.ac.uk/Personal/G.Aggelou/PAPERS/mmt99.ps.gz

> (2) In the simulation of routing protocols one may conclude that it becomes both computationally excessive, as well as requiring assumptions that may not generalize well to simulate the MAC-layer directly. However, MAC-layer contention is an important component that can affect network-layer performance. Hence, it seems that it should be accounted for in some way that is as general and as computationally efficient as possible.

Even there are several simulators dealing from signal elements to data packets, it is a common simplicative approach not simulate the whole system. And this is also related to your question number three: MAC delay can be very important, but applications are likely the most important element in simulating a system, and as Prof. Tanenbaum states " .. they are what the systems are bought for". However you can see that some simulations use some simplified model for applications too.

> The question is, does anyone know of any analytical, or empirical models that can be used to estimate the MAC-layer delay that depend on some reasonable set of parameters (eg. node density (mean number of neighbors), mean offered load, etc.) ? For example, Bux derived an analytical expression to model the delay on an ethernet (802.3) network given a reasonable set of assumptions and parameters.

A certain MAC layer is only a framework, so in order to obtain the delay you can expect from MAC layer you should know the coding scheme and the wireless adapter signal level features and the propagation environment (i.e., BER, propagation exponent, etc).

> (3) What sort of workload models can people suggest? It seems that CBR sources with uniform traffic distributions (random selection of source-destination pairs) is quite common in recent ad-hoc simulations. What other models are being used? Is something like tcplib outdated because it does node reflect current Internet traffic?

Related to my previous comment I see that CBR can be a simple model, but my question here is: what application service this CBR data is modeling? If you want a more realistic packet source model, you'll have to fix the applications that run in the mobiles (which likely is not know in advance, because it can depend on the network capacity too)….

Hidden Terminals

Y. C. Tay (mattyc@leonis.nus.edu.sg)
Sat, 13 Nov 1999 09:01:32 +0800 (SST)

…I'm looking for an analytical model for hidden terminals. The only one I've come across used p_ij, the probability that station i cannot hear station j, with these probabilities being independent of each other. This doesn't seem like a realistic model.

Re: Hidden Terminals

jacquet@menetou.inria.fr
Sat, 13 Nov 1999 17:20:09 +0100

…I think your model is related to the random graph model. Models are never realistic, However it seems to make sense if p_ij depends on the distance between node i and j. If p_ij is a constant, therefore this would be exactly the random graph model which is relevant for short range network where propagation attenuation comes more from obstacles than from distances.

We are currently working on the random graph model applied to some Manet protocols.

Re: Hidden Terminals: Independence Assumption

basagni@utdallas.edu
Sat, 13 Nov 1999 15:17:19 -0600 (CST)

> My problem is with the assumption that p_ij's are independent.
>
> Consider i and i', both the same distance from j, think about i and i' beside each other, or i and i' on opposite sides of j.

As described in detail in:

```
@article{ChlamtacF99,
  author      = "Chlamtac, I. and Farag\'o, A.",
  title       = "A New Approach to the Design and Analysis of  Peer-to-Peer Mobile Networks",
  journal     = "Wireless Networks",
  volume      = 5,
  number      = 3,
  pages       = "149--156",
  month       = "May",
  year        = "1999"
}
```

it is difficult to consider an ad hoc (or peer-to-peer) network as a random graph. In that paper, the authors enrich the standard RG setting with rather sophisticated techniques that consider the dependencies among the links of the nets but still the p_ij does not consider the distance among nodes i and j, and this is another issue that does not allow us to use RG as a reasonable model. That is too bad because the RG model has three great things (among others): 1) The bigger is the network the better (more accurate) are the results (scalability), 2) many problems that in a common network setting would be computationally hard are easily computable (e.g., independent sets, i.e, clustering) and 3) several great results are already available.

> > We are currently working on the random graph model applied to some Manet protocols.

When time allows, in cooperation with Ivan Stojmenovich (U Ottawa), we are looking at a model that consider both distance and dependencies. But we have no results yet ...

Bluetooth capabilities over 802.11/HyperLan?

From: Phil Neumiller (Phillip.Neumiller@motorola.com)
Date: Tue May 30 2000 - 17:08:44 EET DST

I have a question. In looking over the list of work in progress in manet, I see that some really basic stuff is missing. For one, it seems quite plausible to me to facilitate ad hoc networking at the IP layer (using IPv6 neighbor discovery), over any radio link, i.e. Bluetooth or 802.11 or HyperLan for that matter.

My gut feeling is that the designers of Bluetooth went a bit too far up the stack when they added "ad hoc" networking and other baggage to the Bluetooth recommendation. It seems to me that what we want to do is have manet-like capabilities specified at the IP layer so that we can change out radios as needed. With this in mind, can somebody write a draft that puts these really basic Bluetooth capabilities like cable replacement, ad hoc networking, over manet so that we eventually have an RFC standard for the really basic stuff?

Re: Bluetooth capabilities over 802.11/HyperLan?

From: Charles E. Perkins (charliep@iprg.nokia.com)
Date: Wed May 31 2000 - 18:02:08 EET DST

> It seems like the manet work in progress (drafts) and RFCs all address some particular aspect of ad hoc ROUTING: (AODV, TORA, DSRP, ODMRP, OLSRP, INSIGNIA, RDMAR, STAR) yet am I to assume that all these are the "baseline manet architecture"? Is manet just routing? What can I build today that works but is not necessarily optimal and where is THIS specified? What seems to be missing is the manet equivalent of the Mobile-IP RFC 2002 (which I am sure you are intimately familiar with :-). Maybe its too soon for this sort of thing?

I think that you are looking for a "system", and IETF working groups tend to make protocols instead of systems. Indeed, I also think that many people wish to make Mobile IP into a self-contained system, even though it was always designed as a single protocol. I think other protocols (e.g., SIP) may fall prey to the creeping feature creature in an attempt to become systems instead of protocols.

I wouldn't say that manet has to be exclusively concerned with "just routing", and I support Scott's call for drafts dealing with autoconfiguration and service discovery. Indeed, we have made AODV drafts that include text concerned with just those issues. It's not too soon, especially if you have some good ideas about these things.

> OK, it may not be missed, but I know that Microsoft is going ahead and binding Winsock to RFCOMM (a Bluetooth serial port emulator), and I think this is a bad idea. There are probably other product plans being based on Bluetooth's ad hoc capabilities rather than IP's. This is my concern. What I would like to see (if somebody has more bandwidth than me), is a simple specification of what it means to be ad hoc in the IP sense. For instance does this mean that I must use NDP when IPv6? Does this mean I use ICMP messages of some sort when I am IPv4?

IP is good for transmitting packets over a link, and for hooking together networks. It's not good for managing link-specific details. What it means to be ad hoc in the IP sense is to create a network by putting together links as needed at the time (in an ad hoc way).

I think that NDP is expected to be used when all nodes on the same link share an IP address routing prefix. This is not necessarily true in an ad hoc network. I also believe that the IPv6 case for network prefixes that can be shared by nodes that are not "on-link" is poorly specified at present, and may not work well in the ad hoc environment.

If Microsoft jumps the gun and creates APIs based on programming models that are currently incomplete, the fault cannot necessarily be laid at the doorstep of the IETF. As best I can remember, no one from Microsoft (and precious few from Bluetooth) has ever contributed to a manet working group meeting. I have quite often suggested that AODV would be a

good choice for gluing together scatternets, but I am unable to really champion this at Microsoft or at the various Bluetooth venues, so it may go nowhere. Perhaps what is needed is some Proposed standard protocols from the manet working group.

Re: Bluetooth capabilities over 802.11/HyperLan?

From: Fred L. Templin (templin@erg.sri.com)
Date: Wed May 31 2000 - 20:04:52 EET DST

> Maybe I'm missing something, but it seems to me that MANET routing protocols should operate between the data link layer and network layer. That means that IPv6 wouldn't care if it was running on top of a MANET or a wired network.

I think this digs at the heart of the matter. I really believe that what goes on with MANET-style routing can thought of as a lower-level network layer function that is almost (but not quite!) akin to a datalink layer bridging function with dynamic topology discovey capabilities. Although the OSI reference model is largely deprecated with respect to Internetworking discussions, one might think of MANET routing as a layer 3a (subnet access layer) function and Internet routing as a layer 3c (internet layer) function.

We have implemented a MANET-style routing protocol called Topology Broadcast with Reverse Path Forwarding (TBRPF) by using IP host routes (we support both IPv4 and IPv6) that enable an intra-domain multihop relaying capability within the domain of an individual mobile ad-hoc network. In our implementation, these host routes have either IEEE 802 link-layer address resolutions for single hop neighbors or the IPv4/v6 address of the next relay hop in the path to reach multi-hop destinations. We additionally support inter-domain routing by exchanging aggregated IPv4/v6 network prefix routes via traditional Internet routing protocols (such as RIP, OSPF, etc) to enable routing between multiple mobile ad-hoc networks and/or the fixed Internet infrastructure. In this way, our host routes are managed by TBRPF and implement the layer 3a function while the aggregated prefix routes are managed by traditional Internet routing protocols (such as RIP, OSPF, etc) and implement the layer 3c function. In general, we believe the IP-based approach provides greater flexibility than delving into the datalink layer, but I'd like to provide the following discussion as to one reason why I think this is so.

My intuition is that a datalink layer approach may be acceptable for MANETs in which the mobile nodes by-and-large "stick together", but the IP-based approach has distinct advantages for MANETs in which the mobile nodes roam about independently of one another. An example of the former might be a Bluetooth-based PAN in which a user has a collection of personal devices which either rarely leave his possession or are rarely shared with other users. In this case, if the MANET function is perfomed at the datalink layer, each device can be assigned an IP address with a common prefix and each device need only maintain an aggregated route for the common prefix - not individual host routes. The user could end up transmitting a message that gets relayed from his laptop, through his cell phone, through his palm pilot and to his printer without the IP layer ever being aware of the multi-hop situation. In essence, the PAN looks just like a wired Ethernet from the standpoint of IP since the Bluetooth datalink layer performs the MANET routing function transparently.

But, in cases in which the mobile nodes in MANETs roam about independently of one another, nodes may frequently change their current MANETs of affiliation. In this case (which I believe will be the rule rather than the exception) it is no longer reasonable to expect that the nodes in the MANET will all have a common IP network prefix (unless some form of dynamic address assignment is used). Instead, the MANETs will over time become heterogeneous conglomerations of nodes with different IP network prefixes. Therefore, it will not be possible to assign aggregated prefixes for intra-MANET routing. Instead, host routes which are dynamically created/modified/deleted in response to topology changes will be necessary to support intra-MANET multi-hop relaying and something like MobileIPv6 will be necessary to keep track of roaming nodes that have left their "home" MANETs.