Mobile Ad-hoc Intern-domain Networking

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***Abstract*— After nearly three decades of work on mobile ad-hoc networking we are starting to see a convergence of better radios and better understanding of performance needs for MANET routing schemes, delivering working networks. One part of the next stage of evolution of such systems will be to support the federation of different MANETs together, whether concatenated together or interleaved. In this paper, I present some initial thoughts on how one might start to tackle this interesting problem space, which appears to be rather more complex than the still contentious area of Inter-domain routing in the Internet which the creation of BGP attempted to address.**

***Index Terms*— General Terms: Algorithms, Performance, Design Keywords: Data Communications**

I. Introduction

The area of MANET Routing [1] is a morass of different schemes, suited to a variety of different circumstances. There are so many dimensions for which one might try to optimise and trade-off that its hard to visualise, but, remembering that MANET was historically rooted in a world of scarce resource, then it is not hard to see why one considers minimizing computational overhead, routing control traffic overhead, forwarding table memory consumption, energy and so on. Given that we are interested in mobile scenarios, then it is also natural to include mobility models as part of the evaluation framework, and sensors that report location, velocity and acceleration as possible inputs to algorithms.

Thus we have proactive versus reactive routing, and we have geographic versus topological routing, as two key axes of design along which a range of protocols have been devised. In the metric space we have capacity, delivery success, power (receive as well as transmit), hybrid measures such as ETC, and so on and so forth. Multicast schemes, as with fixed and wired networks, leverage typically from the unicast schemes, although use of the broadcast nature of the medium (as with 1988 IP multicast on shared medium Ethernet) has some positive impact on design.

Recent promptings at the lack of workable algorithms for deployment with today's commonplace 802.11 (and other higher capacity wireless) links led to the development of a more traditional link state schemes, such as OLSR.

As more realistic and deployable schemes appear, and radio links improve, it is inevitable that users will start to interconnect MANETs, not just to core infrastructure networks, but also to each other.

This paper is a survey and discussion of some considerations that designers of Inter-domain MANET Routing algorithms may wish to take.

A. Assumptions on Data Plane

One of the key areas to sort out first is what the assumptions we have for interworking in the data plane for MANETs, as this will set goals for what is done in the control plane.

Different MANETs are targeted at different operating situations, and different application requirements in terms of service. For example, a network that incurs a delay at the start of any session, since, perhaps, time critical applications do not run, is happy to employ some on-demand routing scheme. On the other hand, systems that do not have heavy traffic load might use multi-path routing (in fact, depending on the multipath routing scheme, this might suit heavy traffic loads too!). Systems that do not care about battery life (e.g. vehicular ad hoc) might not mind the overhead of the route maintenance chatter of a proactive routing scheme. Systems where location is a vital application need anyhow (satnav etc) will be able to use it as part of routing if they like. Systems that run indoors will not have access to GPS (although one could assume some building-based location service such as active badge systems is available, but that would be exceptional) so a topological routing scheme is more likely

In interworking across these schemes, one can take one of two approaches.

- Lowest common denominator
  We could just support the least functionality of any route and pick a single metric for all possible paths. The control plane would then be free to operate also with the least complex option (e.g. on-demand, source planned, topological, rather than, say pro-active, distributed, geographical).
- Multi-metric
  We would need to describe capability and performance differences at ingress/egress - e.g. proactive versus reactive... - startup time, multicast capable or not, link level reliable or not, policy e.g. secure or not, diffusion (for sensor support) or not and so on.

As well as this, at each border, we need to be able to describe classical inter-domain routing rules such as "transit or not", ingress/egress filtering, etc, just as is done in the Internet today with BGP.

B. Assumptions on Control Plane

In inter-networking in control plane itself, we need to solve certain problems that are different in a connecting a *set* of wireless networks, than the classical Internet interconnection of *wireline* Autonomous Systems (ASs). Inter-MANET is not just promoting a MANET like protocol to inter-domain level need some other propagation mechanism! It is possible that we can use BGP when connecting MANETs to a fixed infrastructure, but it is unlikely that a path vector scheme will work as a distribution mechanism between MANETs.

- Where are the borders? Are they anywhere within MANET, or only some or even at fixed points.
- How to advertise capability? What format, how often? We cannot just do link state, or distance vector, as all the known problems (e.g. traffic load and slow convergence/intermittent loops, respectively) will be even worse in this scenario.
- How to deal with the asymmetric case There is potentially no path over a proactive routed MANET until you want it and use it.
- IGP/EGP Interworking
  Do we flood externally reachable *prefixes* or just provide them on demand or perhaps use some scoped distribution, only advertising other AS/addresses up to a certain distance outside, and into the inner net a certain distance inside. Perhaps it could be IGP dependant.
- Convergence: We merely note that in the fixed Internet, IGPs tend to converge fast (recently, sub-millisecond OSPF convergence has been discussed), but in inter-MANET, we cannot make such an assumption at all.
- Link Status Changes: Much more so than in the fixed Internet, link up and down status mean quite different things. Propagating such internal information rapidly in between interconnected MANETs is almost certainly not useful.
- Exotic MANET types: We note also MANETs exist that do all-paths forwarding, and some do net coding, and there are other odd cases that may be devised for specialised deployment.

It is clear that there is a strong push towards using OLSR for larger, more stable MANET deployments, especially as battery life and radio link capacity increase. This is one of the easier cases to consider, if OLSR is considered (as historically was the case with the ARPANET) a *core*, around which stub MANETs are configured. Then one can certainly use BGP as an interworking scheme, although the iBGP (intra-domain side of BGP that imports/exports routes from within the MANET) component facing into stub networks that are reactive rather than proactive would be problematic.

II. OPEN QUESTIONS

Some interesting questions arise that are even further away from being resolved.

- Address Allocation: The interaction with name/addressing schemes within each MANET and across MANETs clearly matters. If one assumes an IPv6 environment (by no means a given) one could consider allocating each MANET an AS number, and embedding it in all the nodes' addresses in a given MANET as part of a *provider* prefix. Such an address could be pre-configured, or derived from higher level configured information (e.g. if a Domain Name System is used or similar, one could derive the AS number uniquely from a hash of the organisational prefix in the name Many organisations use hierarchical inventory schemes for equipment, so the radios could derive a group-name/prefix from the group/organisation part of the inventory name, and use this as an Autonomous System number. Routing inter-MANET would then be at the "AS-level", although on reaching a specific AS/MANET, would then be at the normal (IP) addressing level, thus source radios in other MANETs do need to be able to retrieve specific destination addresses in a remote MANET/AS. This can be supported by dynamic DNS or a distributed directory (perhaps a DHT?).
- Multi-homing: How many nodes in each MANET are "borders"? given the dynamics of some MANETs, one might consider, for resilience reasons, much richer interconnect than is typically found at the AS level in today's fixed Internet, which is fairly sparse.
- Change IGP to suit EGP: Would we consider changing a given MANET to meet needs for current set of interdomain flows? For example, consider a sort of TE/MPLS for MANET!
- What are the considerations for inter-connection of multiple MANETs and QoI?
- Programmable Networks: We are increasingly looking at Software Defined Radio in the data plane. Would we also consider mobile code in the control plane? Downloadable MANET routing schemes?
- Performance/feasibility/constraint model: If there's some connectivity/mobility which will tell us whether there is a path/set then this will give us a set of possible protocols, and whether the protocol would be stateless or memory based. Following on from that, is there a percolation model for where the various percentage of nodes in each MANET reach a threshold for phase shift to likelihood of MAIN working? This is definetl a subject for future work, since it will provide a fundamental insight into heterogeneity of multihop wireless networks at the connectivity level.

III. STRAWMAN PROPOSAL

I propose that we make the route dissemination protocol source based, landmark oriented (at the AS) and proactive in terms of distributing topological information at the AS level. However, at the data plane level, I propose the system of inter-connected MANETs should be traffic driven, i.e. reactive rather than proactive.

I would propose a scheme like NIMROD (or like the late lamented PNNI routing scheme in Broadband ISDN/ATM standards), which employs a map distribution with a hybrid of speculative and lazy evaluated map for reactive routing into the innards of each MANET, and normal (aggregated) for advertising topology into proactive regions

To carry an AS level route advertisement across a reactive domain, we need to create temporary routes so that the advertisements flow. These use relatively little resource, since the AS level topology is presumably relatively slowly changing (although the link status within any specific AS/MANET may be altering rapidly, which is why we do not advertise that!).

A strawman experimental plan for work in the ITA Project on this is as follows.

1) Firstly we need to consider the core+stub model, with a core running OLSR< and the stubs running a variety of schemes (OLSR again, but also possibly DSR or AODV, or a geographic scheme like GPSR). This will examine simple application of BGP (eBGP[1] and iBGP) to these cases, looking at the various performance impact of parameters (such as minimum route advertisement intervals, MRAI, in BGP and route flap damping).
2) Secondly we need to consider different topological constraints such as underlay, overlay, interleaving approaches to connecting MANET.s
3) Thirdly we must consider whether changing MANETs (e.g. insisting some fraction of nodes in *any* MANET should have geographic/location service capability) might help. A geo-based hierarchy would certainly make the map distribution proposed above much simpler.

IV. Conclusion and Future Work

We have proposed a framework for Mobile Ad-hoc Interndomain Networking, within which the ITA programme can consider the next stage of evolution of MANETs.

We have discussed the various impacts of interconnecting the wide range of different MANET routing capabilities such as proactive versus reactive, source versus distributed and geographic versus topological routing schemes. We have proposed a strawman solution to interworking based on hierarchical map distribution of AS-level topology like NIMROD, but reactive, source planned routing of actual flows, like DSR. Future work will be to build a large scale simulation model of such a system with realistic topologies and mobility drawn from partners' experience in the ITA Project, and evaluate the scheme for viability and performance.

V. Acknowledgements

We gratefully acknowledge funding from the ITA Programme, and our partners in IBM research and Roke Research for valuable discussion on this topic.

References

[1] E. M.Royer and C. K. Toh, "A review of current routing protocols for ad hoc mobile wireless networks," *IEEE Personal Communications Magazine*, pp. 46–55, April 1999.

[1] eBGP is the external facing component of BGP, which is the main consideration of this paper.